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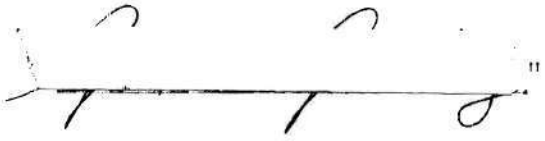

THE EFFECTS OF FREE AND FORCED CONVECTION HEAT TRANSFER IN A HORIZONTAL ISOTHERMAL TUBE

A THESIS

Presented to

the Faculty of the Graduate Division

by

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CONVECTION HEAT TRANSFER IN A
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Approved:

K. R. Purdy, Chairman

C. W. Gorton

J. M. Spurlock

Date Approved by Chairman 1-31-62

ACKNOWLEDGMENTS

I wish to express my gratitude to Professor Kenneth R. Purdy, my thesis advisor, for his valuable advice throughout the experiment.

I would also like to express my gratitude to the Schlumberger Foundation for granting me a fellowship which made it possible for me to obtain my masters degree.

Finally, but far from least, I have to thank my family whose constant encouragement made this work possible.

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SUMMARY

The combined effects of free and forced convection in laminar flow for a horizontal isothermal tube with a hydrodynamic and thermal entrance region were studied.

The volume flow rate of air was adjusted to give Reynolds numbers from 1,000 to 2,000 at increments of 200. The inlet air temperature was varied from 92°F to 155°F for each setting of the Reynolds number.

Free convection was found to have a definite effect on the average heat transfer coefficient for Graetz numbers between 10 and 1,000. For values of the Graetz number above 1,000, the Polhausen solution for a flat plate modified for a tube was found to give accurate results. For Graetz numbers below 10, Kays' solution gives acceptable results.

The equation for the average Nusselt number that correlated the results of this experiment was

$$Nu_{lm} = (0.0129\ Gz + 11.40)\left[\frac{Gr}{1.5 \times 10^6}\right]^{(0.722\ -\ 0.0911\ \ln Gz)}$$

in the range

$$30 < Gz < 1{,}000$$

For values of the local Graetz number between 10 and 30, the following equation fits the experimental values of the local heat transfer coefficients,

$$Nu_x = 0.0198\ Gz_x^{5/3}$$

Graphs were drawn for the local and average values of the Nusselt number as obtained from the experiment, and as calculated from previous solutions by Graetz and Kays to show the influence of free convection, and entrance conditions.

CHAPTER I

INTRODUCTION

Objective.--The problem under investigation is that of determining experimentally the local and average heat transfer coefficients for laminar flow in a horizontal isothermal tube with a thermal and hydrodynamic entrance region when both free and forced convection are present.

The principal purpose was to correlate the local and average Nusselt numbers as functions of the Graetz and Grashof numbers.

Previous Investigations.--Solutions for laminar-flow, forced-convection heat transfer in a horizontal isothermal tube have been obtained for various velocity profiles.

Graetz integrated the general energy differential equation for heat convection for two different velocity profiles. Forced convection, and a uniform velocity profile throughout the tube, were first assumed; this would be a fair approximation for fluids having very low Prandtl numbers. A second solution resulted from assuming forced convection and a fully developed parabolic velocity profile. Both solutions are in the form of infinite series (2). Hausen has proposed the following equation as an empirical representation of the Graetz solution for constant wall temperature, fully developed parabolic velocity profile (8):

$$Nu = 3.65 + \frac{0.0668(D/x)\ Re.\ Pr}{1 + 0.04[(D/x)\ Re.\ Pr]^{2/3}}$$

W. M. Kays (1) performed a numerical integration of the same differential equation assuming forced convection only, with a thermal entrance region, and using the hydrodynamic entrance region suggested by Langhaar. Kays' solution is valid for Graetz numbers less than 800. For Graetz numbers above 800, Kays suggested the use of Polhausen's equation for a flat plate modified for a tube. In verifying his solution with experimental results, Kays stated that it was necessary to use tubes of 1/4 inch diameter or less to avoid free convection effects. Kays' solution would then be a lower limit for the problem under investigation here. The results of Kays' work and the Polhausen solution are shown in Figure 11, page 31.

Many empirical equations for combined free and forced convection, such as Jackson's (4), and Martinelli's(6), to determine the Nusselt number as a function of the Graetz and Grashof numbers have been suggested.

CHAPTER II

APPARATUS

The components of the experimental apparatus are as follows:

(a) Steam heated test section

(b) Condensate collection system

(c) Air supply system

(d) Temperature measuring and controlling equipment

(a) Steam Heated Test Section.--The test section was a 10.5 feet long by 4.125 inches in outside diameter type K copper tube which was mounted concentrically within a 16-inch steel pipe. The annular region between the tube and the pipe, which formed the steam chest, was supplied with saturated steam from the low pressure steam line in the laboratory. A globe valve was used to regulate the pressure in the chest to approximately 4.5 inches of water. The saturated steam provided an essentially isothermal test section. A copper sheet was placed over the test tube to prevent any extraneous condensate from dripping into the condensate collectors. The surplus steam and the condensate from the chest were exhausted through an orifice in the bottom of the steam chest. The orifice throttled the steam and prevented excessive waste. A by-pass between the inlet and the outlet steam line was included to prevent the condensate from the laboratory steam line from entering the steam chest. A water spray condensed the steam as it entered the drain. The steam chest was insulated with fiberglass roll insulation.

The temperature of the tube wall was measured by two 24-gauge copper-constantan thermocouples, one placed 4.5 inches from the entrance, and the other 3 inches from the exit of the test section. A third thermocouple was used to determine the saturation temperature of the steam. The leads were taken out through the brass head plate at the entrance of the test section and sealed with Conax thermocouple gland seals.

(b) Condensate Collection System.--The condensate collection system consisted of 21 chambers. The chambers were divided by diamond-shaped discs cut from 48-gauge copper sheets. The discs were soldered to the test tube at three-inch intervals for the first two chambers, and at six-inch intervals for the remaining 19 chambers. The first chamber started 0.38 inches from the entrance of the test section. The chambers were completed by soldering a preformed collection pan in the shape of an inverted hollow pyramid to the bottom of each chamber. A hole in the bottom of each pan allowed the condensate to drain into a 5/16 inch O. D. copper tube. The drain lines ran horizontally through the steam chest, and then through the brass head plate at the entrance end of the test section. The lines were made to run horizontally through the chest to avoid the collection of extraneous condensate due to the heat loss that would be present if the drain lines ran straight down through the chest. One-fourth-inch O. D. copper tubing was used to transfer the condensate from the head plate to the outside wall of the air-conditioned room where the test section and air supply system were installed.

One-fourth-inch O. D. Neoprene tubing was used between the copper drain lines and the 21 transfer cups (Figure 2, page 22).

The transfer cups were open to the atmosphere so that each drain line acted like a U-type manometer. The 21 transfer cups were mounted on a rack which was free to move up and down. The rack was positioned so that the condensate level in the stand pipes was 1/2-inch below the bottom of the collection pans. A pointer attached to the rack, and a manometer which indicated the steam chest pressure were used to position the rack properly. Cotton wicks were used to eliminate the effects of surface tension in the line coming into the transfer cups. From the transfer cups the condensate drained into 21 calibrated burettes where it was measured as a function of time (Figure 5, page 25).

(c) Air Supply System.--The air supply system consisted of an air filter, a centrifugal blower, a gas meter, an air heater, and an inlet plenum chamber. The air was supplied from the air-conditioned room where the steam chest and air supply system were installed. The air temperature at the inlet of the blower was constant within ± 1.0°F. The dry and wet bulb temperature of the air was determined by means of a hygrometer at the entrance of the blower. The blower was housed in a plywood box with the air filter at one end and a header on the outlet side. A pressure tap was connected to the header to determine the static pressure of the air. From the header the air flowed into a Rockwell No. 1600, dry gas meter; a copper-constantan thermocouple was installed on the inlet to the gas meter to determine the air temperature at this point. The

gas meter had a capacity of 1,600 cfh. The air flow was regulated by a gas cock located between the gas meter and the air heater inlet. The air flow rate, as determined by the gas meter, was found to be within a maximum error of + 3 per cent. The heater was a 10 x 8 x 2.5 inch steel box with two electric heaters, one of which was a manually operated 600-watt heater, the other a 45-watt heater controlled by a Leeds and Northrup Series 60 control unit and coupled to a Speedomax Type G Leeds and Northrup temperature recorder (Figure 6, page 26). Baffles were installed in the heater to provide mixing of the air before discharging it into a small chamber in the bottom of the inlet plenum chamber where a thermocouple sensed the temperature and transmitted it to the temperature control unit.

The air heater was put into a large box, and the space between the box and the heater was filled with vermiculite insulation. The air heater was connected to the small chamber in the bottom of the plenum chamber by two one-inch O. D. pipes which were insulated with fiberglass. The chamber at the bottom of the plenum chamber reduced the velocity of the air, and directed the air into the plenum chamber and away from the entrance of the test section. The inlet plenum chamber was built of 3/4 inch plywood with a shell around it made of the same material (Figure 3, page 23). The temperature of the air in the shell around the plenum chamber was kept at approximately the same value as that of the air inside the plenum chamber to avoid any heat loss from the air inside the chamber. The heating in the shell was provided by a 500-watt electric heater, and the air circulation was provided by a small blower placed on top of the shell.

A smooth bell-mouthed entrance section connected the inlet plenum chamber to the test section. The bell was constructed of mahogany and was included to provide a uniform velocity profile entering the tube, and to insulate the entering air from the hot head plate of the test section.

After flowing through the test section the air entered the exit plenum chamber, which was also made of wood. The air left this plenum through a well-baffled chimney which mixed the air before it flowed over the outlet air thermocouple. The air was discharged into the air conditioned room.

(d) Temperature Measuring the Controlling Equipment.--All the thermocouples used in the heat transfer apparatus were made from 24-gauge copper-constantan duplex thermocouple wire. The voltage produced in the thermocouples was measured by a Leeds and Northrup Type 8686 Millivolt Potentiometer. The saturation temperature read in the potentiometer was within 0.5°F of the saturation temperature determined from the saturation pressure (10). The latter one was used in the calculations.

The inlet air temperature was controlled by two electric heaters. One of these was a 600-watt heater connected to a manually operated variable rheostat and was used to bring the air temperature to within a few degrees of the desired value. The other was a 45-watt heater whose power output was controlled by a Series 60 Leeds and Northrup control unit coupled to a Speedomax Type G Leeds and Northrup temperature recorder and it was used to maintain the air temperature at the desired value. The inlet temperature was constant within ± 0.8°F.

The power input to the inlet plenum chamber shell heater was controlled by means of a manually-operated variable rheostat of the same type as the one used in connection with the inlet air heater. The air temperature in the shell was read on a Leeds and Northrup temperature indicator.

CHAPTER III

EXPERIMENTAL PROCEDURE

Each run was started by adjustment of the air flow rate and temperature to the desired values. The temperature in the shell surrounding the inlet plenum chamber was adjusted to the proper value to avoid heat losses from the inlet air, and thus to insure that the air temperature at the inlet of the test section was the same as that sensed by the thermocouple in the small chamber at the bottom of the inlet plenum chamber. Since the apparatus was running constantly there was no need to adjust the steam pressure which remained constant at 4.5 ± 0.2 inches of water throughout the experiments.

After the desired air flow rate and temperature were obtained, the apparatus was allowed to run overnight to obtain thermal equilibrium before any data were recorded.

The burettes were filled with a mixture of water and a wetting agent and drained to a value close to the initial setting. An electric timer was started; the burettes were then drained to the initial reading at the same pace that the condensate readings were taken to insure that each burette was read at exactly the same time interval. Initial readings were also taken of the gas meter, temperatures, and barometric pressure.

During each experiment, readings were taken at constant time intervals of one or two hours depending on the air flow rate and

air temperature. The longer time corresponded to the lower Reynolds numbers or higher inlet air temperatures.

Each reading was recorded in the same sequence to compare air flow rates, condensation rates, pressures, and temperatures during each period. This provided an additional check on the steady state behavior of the system.

The air flow rate was adjusted to give values of the Reynolds number from 1,000 to 2,000 at increments of 200. The inlet air temperature was kept at 92, 110, 125, 140, and 155°F for each value of the Reynolds number.

Each experiment lasted for at least eight hours. Unless erratic discrepancies occurred, the readings were averaged for the duration of the test run, and the average values were used in the calculation procedure. When erratic discrepancies occurred in the condensation rates in any experiment, the condensation rates for the chambers that ran steadily were plotted and a smooth line was drawn through these points. Values taken from these graphs were then used in the calculation procedure. For any one run there were never more than three chambers that ran erratically.

CHAPTER IV

DISCUSSION OF RESULTS

The average Nusselt Numbers obtained in the experiment were plotted versus the Graetz, and Grashof numbers; from these plots, a new graph was made of average Nusselt number versus the Grashof number for constant Graetz number (Figure 8, page 28). The latter graph was made up of a set of straight lines, each having a different slope, on log-log paper: therefore, an equation of the following form was used to correlate the results

$$\ln\left(\frac{Nu_{lm}}{c}\right) = M \ln\left(\frac{Gr}{B}\right) \qquad (1)$$

or

$$\frac{Nu_{lm}}{c} = \left(\frac{Gr}{B}\right)^{M}$$

where

B = intercept of the constant Graetz lines = 1.5×10^6,

c = values of the Nusselt number at B, and

M = slopes of the constant Graetz lines.

Graphs were also drawn to find an expression for M, and c as functions of the Graetz number (Figures 9 and 10 pages 29 and 30). The correlating expressions found were

$$M = 0.722 - 0.0911 \ln Gz$$

and

$$c = 0.0129\ Gz + 11.40$$

which when substituted into equation 1 gives an expression for the average Nusselt number,

$$Nu_{lm} = (0.0129\ Gz + 11.40)\left[\frac{Gr}{1.5 \times 10^6}\right]^{(0.722\ -\ 0.0911\ \ln\ Gz)} \qquad (2)$$

Equation 2 was found to fit the data within an error of + 10 per cent, and - 7 per cent in the range (see Table 3)

$$50 < Gz \quad 1{,}000$$

For values of the Graetz number between 50 and 30 equation 2 gives a value for the average Nusselt number within a maximum error of + 20 per cent, and - 7 per cent.

The properties of air in equation 2 are taken at the average film temperature T_f, defined as follows

$$T_f = \frac{\frac{T_o + T_w}{2} + \frac{T + T_w}{2}}{2}$$

where

T_o = inlet air temperature,

T_w = wall temperature of the tube, and

T = fluid temperature at the point of interest, or at the point where the Graetz number is 30, whichever occurs first in the tube.

The average Nusselt and Grashof numbers are based on the logarithmic temperature difference

$$\Delta T_{lm} = \frac{T - T_o}{\ln \frac{T_w - T_o}{T_w - T}}$$

which can also be written (see Calculation Procedure Part I, in the Appendix),

$$\Delta T_{lm} = (T_w - T_o) \frac{Gz}{\pi Nu_{lm}} \left(1 - e^{-\frac{\pi Nu_{lm}}{Gz}}\right) \qquad (3)$$

The Grashof number is defined as

$$Gr = \frac{\rho^2 \beta g D^3}{\mu^2} \Delta T_{lm}$$

and substituting equation 3 for ΔT_{lm},

$$Gr = \frac{\rho^2 \beta g D^3}{\mu^2} (T_w - T_o) \frac{Gz}{\pi Nu_{lm}} \left(1 - e^{-\frac{\pi Nu_{lm}}{Gz}}\right) \qquad (4)$$

Substitution of equation 4 into equation 2 shows that equation 2 is implicit in the Nusselt number. The following iterative procedure can be used to solve for the average Nusselt number:

(1) A value for the average Nusselt number is assumed and used in equation 4 to solve for the Grashof number.

(2) The value thus obtained for the Grashof number is then used in equation 2 to solve for the average Nusselt number.

(3) The new value for the average Nusselt number obtained from equation 2 can now be used to calculate a new value for the Grashof number. This procedure is repeated until the value obtained from equation 2 for the average Nusselt number is very close to the previous value.

As a first approximation to the value of the average Nusselt number, the following equation is suggested,

$$Nu_{lm} = 1.74\ Gz^{0.4} \tag{5}$$

which approximates the values of the line joining Kays' solution and Polhausen's equation modified for a tube.

The iterative procedure described above for the solution of the average Nusselt number is quite rapid since the values of the Nusselt number converge rapidly.

Equation 2 can be used for Graetz numbers in the range,

$$30 < Gz < 1{,}000$$

For Graetz numbers above 1,000, Polhausen's equation modified for a tube gives very accurate results. For Graetz numbers less than 10, Kays' solution gives acceptable results. As can be seen in Figure 11, for the high values of Graetz numbers, the experimental curves very closely approach the Polhausen solution; while at low values of the Graetz number the experimental lines are dropping toward Kays' solution.

Although for Graetz numbers between 10 and 30, equation 2 fails to give reliable results, an equation was found for the local Nusselt

number as a function of the Graetz number which fits the data well (Figure 12, page 32).

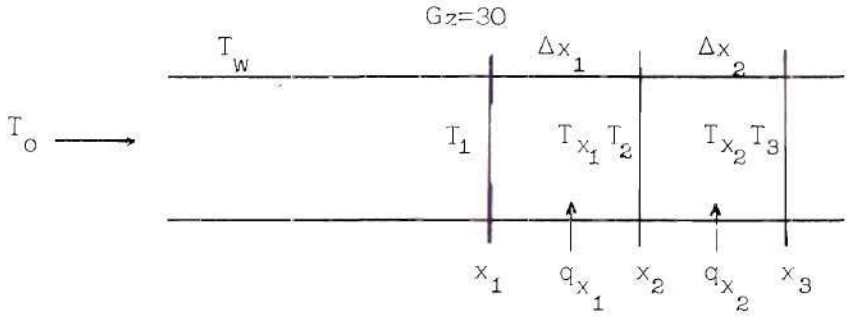
$$Nu_x = 0.0198\ Gz_x^{5/3} \tag{6}$$

If the total heat transfer rate from the entrance to a point in the tube where the Graetz number is between 10 and 30 is to be determined, the following procedure may be followed:

(1) Divide the tube in small Δx regions from the point where the Graetz number equals 30 to the point of interest.

(2) Use equation 2 to calculate the heat transfer from the entrance to the point where $Gz = 30$, and also the air temperature at that point.

(3) Compute the local heat transfer rate in each small Δx region from the point $Gz = 30$ to the point of interest as shown below.



$$_oq_{x_1} = h_{lm} A \Delta T_{lm}$$

where

$_oq_{x_1}$ = heat transfer from the entrance of the tube to the point $Gz = 30$.

$$ {}_{o}q_{x_1} = \pi \, Nu_{lm} \, k \, x_1 \frac{T_1 - T_o}{\ln \frac{T_w - T_o}{T_w - T_1}} $$

also

$$ {}_{o}q_{x_1} = \dot{m} \, c_p (T_1 - T_o) $$

Equating the last two equations, and solving for T_1,

$$ \ln(T_w - T_1) = \ln(T_w - T_o) - \frac{\pi \, Nu_{lm}}{30} $$

The heat transfer in a small region Δx,

$$ q_{x_1} = h_x \, \pi \, D \, \Delta x (T_w - T_{x_1}) \qquad (a) $$

Assume $T_{x_1} = T_1$

$$ q_{x_1} = h_x \, \pi \, D \, \Delta x (T_w - T_1) $$

$$ = \pi \, k \, Nu_x \, \Delta x (T_w - T_1) $$

Substituting equation 6 for Nu_x, and integrating between x_1 and x_2 (the properties are assumed to be constant, and taken at the average film temperature between x_1 and x_2)

$$ q_{\Delta x_1} = \pi \, k \, (T_w - T_1) \int_{x_1}^{x_2} 0.0198 \, Gz_x^{5/3} \, dx $$

where

$$ Gz = \frac{\dot{m} \, c_p}{k \, x} $$

$$q_{\Delta x_1} = 0.0297\ \pi k\left(\frac{\dot{m}\ c_p}{k}\right)^{5/3} (T_w - T_1)\ \left(\frac{1}{x_1^{2/3}} - \frac{1}{x_2^{2/3}}\right)$$

also

$$q_{\Delta x_1} = \dot{m}\ c_p(T_2 - T_1)$$

Solving for T_2

$$T_2 = 0.0297\pi\left(\frac{\dot{m}\ c_p}{k}\right)^{2/3} (T_w - T_1)\ \left(\frac{1}{x_1^{2/3}} - \frac{1}{x_2^{2/3}}\right) + T_1$$

The average film temperature between x_1 and x_2,

$$T_{f_{\Delta x_1}} = \frac{\frac{T_1 + T_w}{2} + \frac{T_2 + T_w}{2}}{2} \qquad (b)$$

The value just obtained for T_2 can be used to get a better approximation for the value of T_{x_1}. Since Δx was assumed to be small, an arithmetic mean will give an accurate approximation to the value of T_{x_1}

$$T_{x_1} = \frac{T_1 + T_2}{2} \qquad (c)$$

This new value of T_{x_1} is used in equation (a) to calculate a new heat transfer rate, which in turn gives a new value for T_2 that is substituted into equations (b), and (c). This iterative procedure is repeated until the value obtain for T_{x_1} in two consecutive operations is the same. To obtain the heat transfer in the next Δx region, T_2 is used

as the first approximation for the value of T_{x_2}. This procedure is repeated until the point of interest (x_n) is reached.

The total heat transfer, from the entrance of the tube to the point x_n is then

$$_{o}q_{x_n} = {}_{o}q_{x_1} + \sum_{n=1}^{n} q_{\Delta x_n}$$

where x_n is the point in the tube where the Graetz number has a value between 10 and 30.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

It is concluded from this investigation that free convection has a definite effect on the average heat transfer coefficient for laminar flow in a horizontal isothermal tube in the range of the Graetz number between 10 and 1,000.

For values of the Graetz number greater than 1,000, Polhausen's solution for a flat plate, modified for a tube, will give accurate results. For values of the Graetz number less than 10, Kays' solution can be used.

The equations obtained in this experiment apply to air only. In order to determine more general equations, more experiments should be run using fluids of different Prandtl numbers. Experiments should also be run with tubes of different diameters to obtain a wider range of Grashof numbers, since in this experiment the Grashof number was varied by changing the inlet air temperature only.

A P P E N D I X A

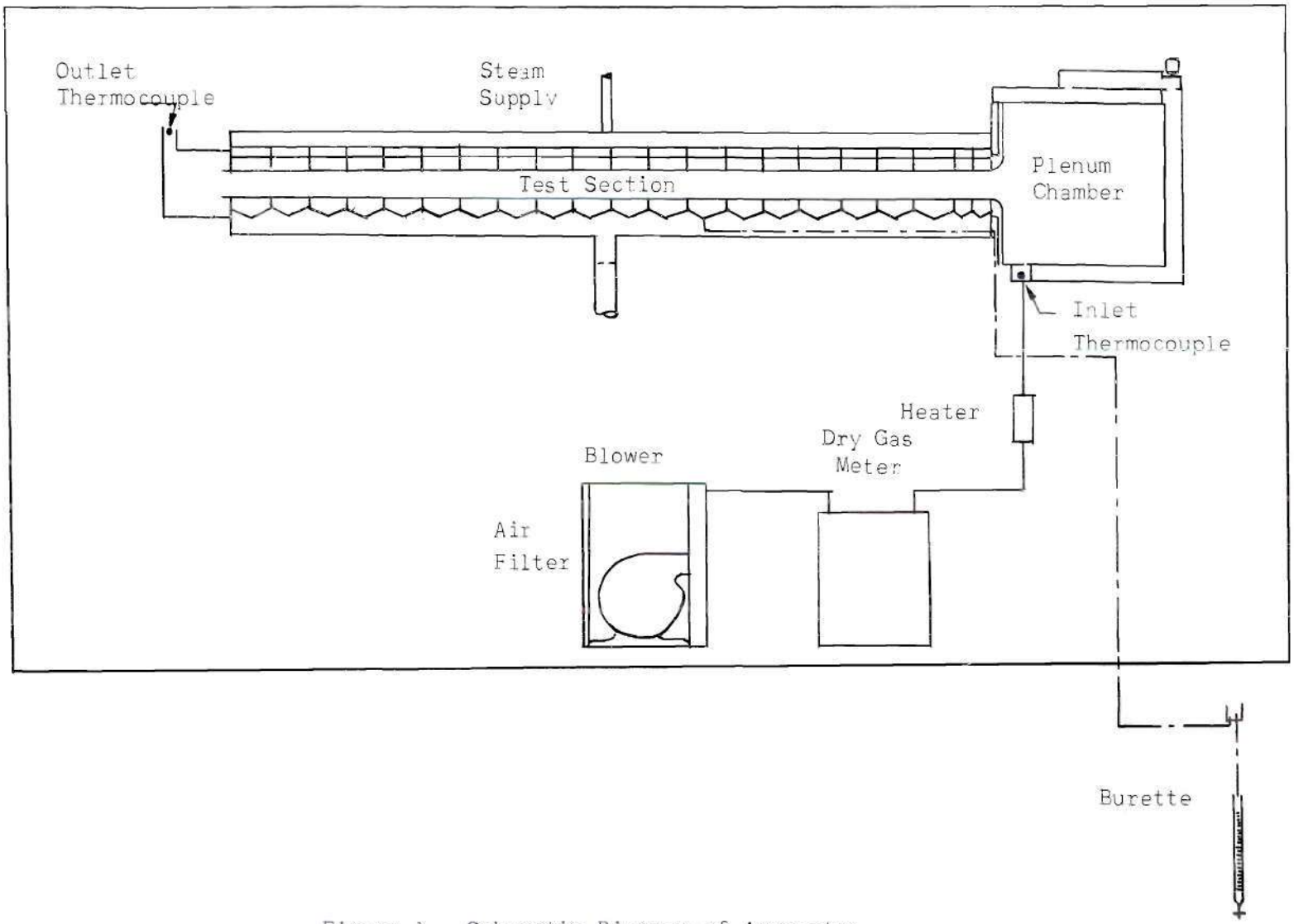


Figure 1. Schematic Diagram of Apparatus

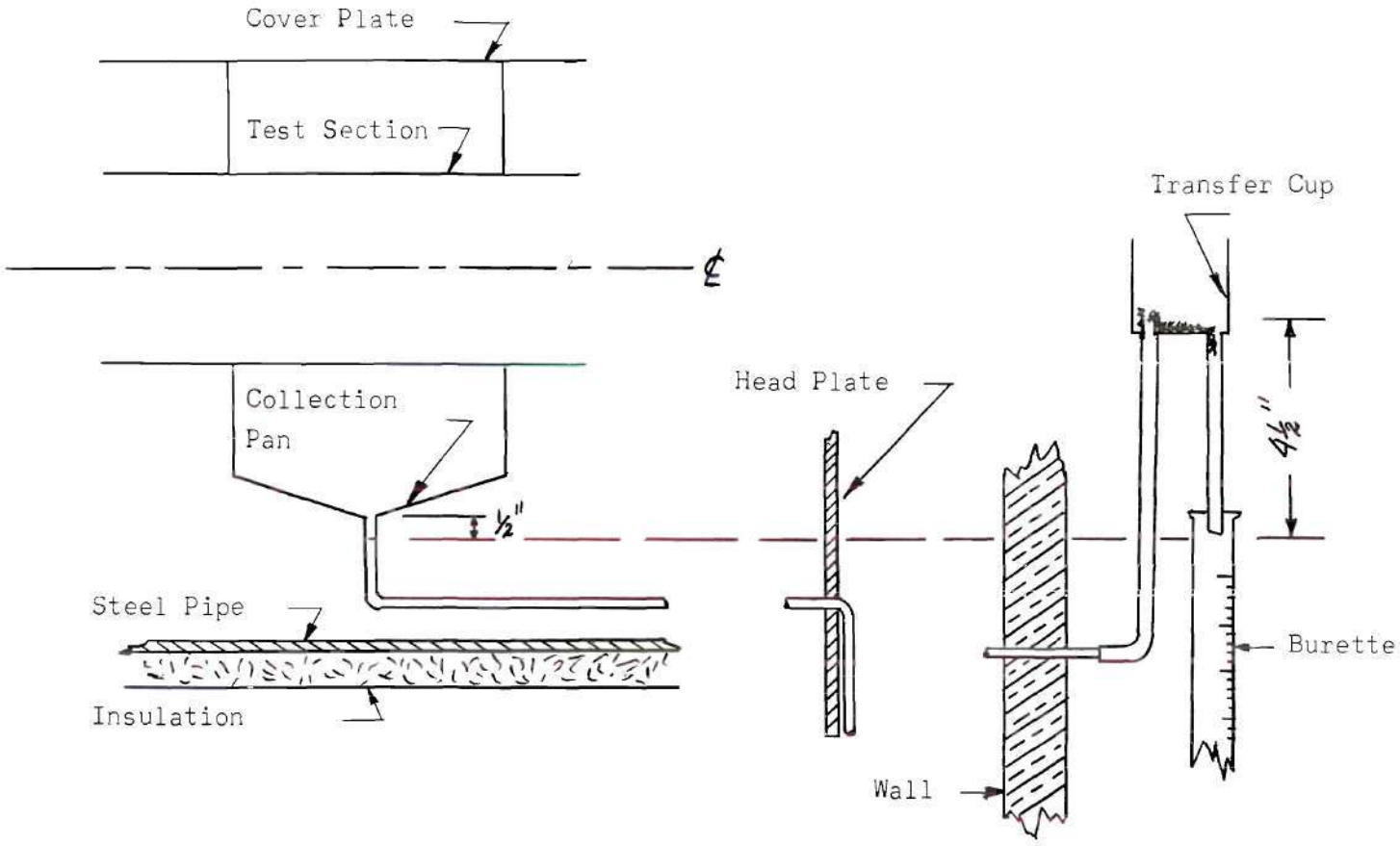


Figure 2. Schematic Diagram of the Condensate Collection System

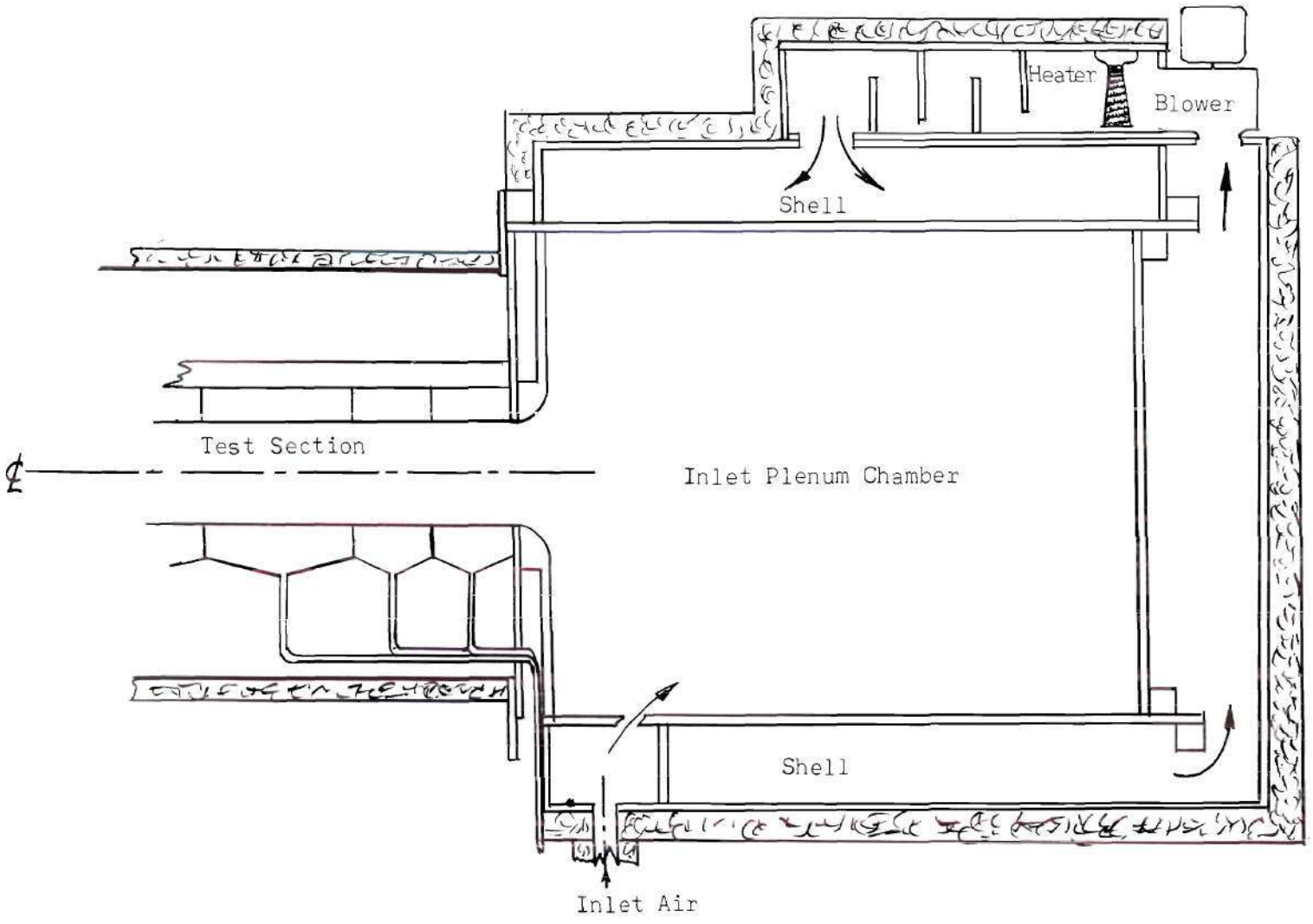


Figure 3. Schematic Diagram of the Inlet Plenum Chamber

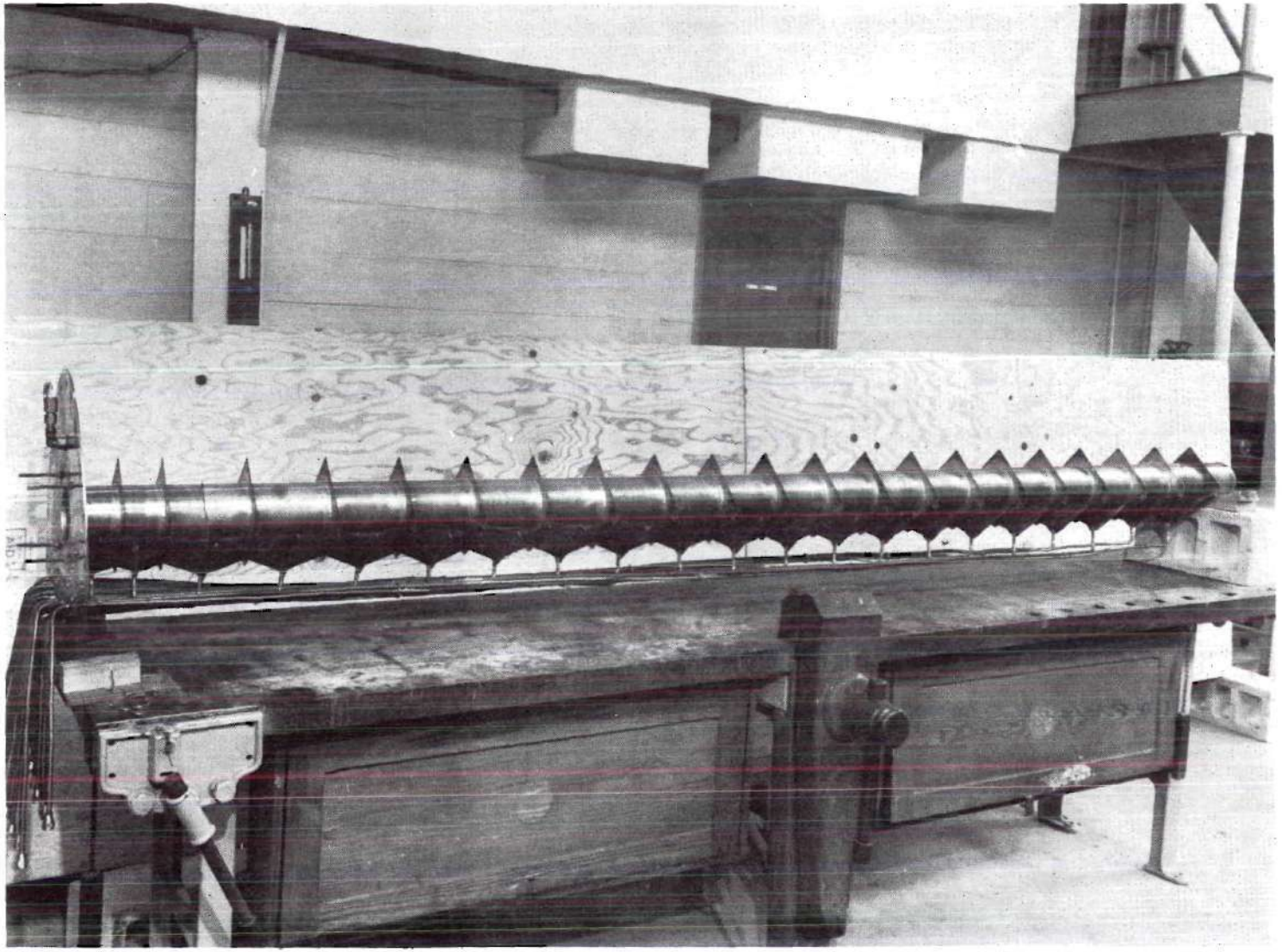


Figure 4. Test Section Showing Condensate Chambers.

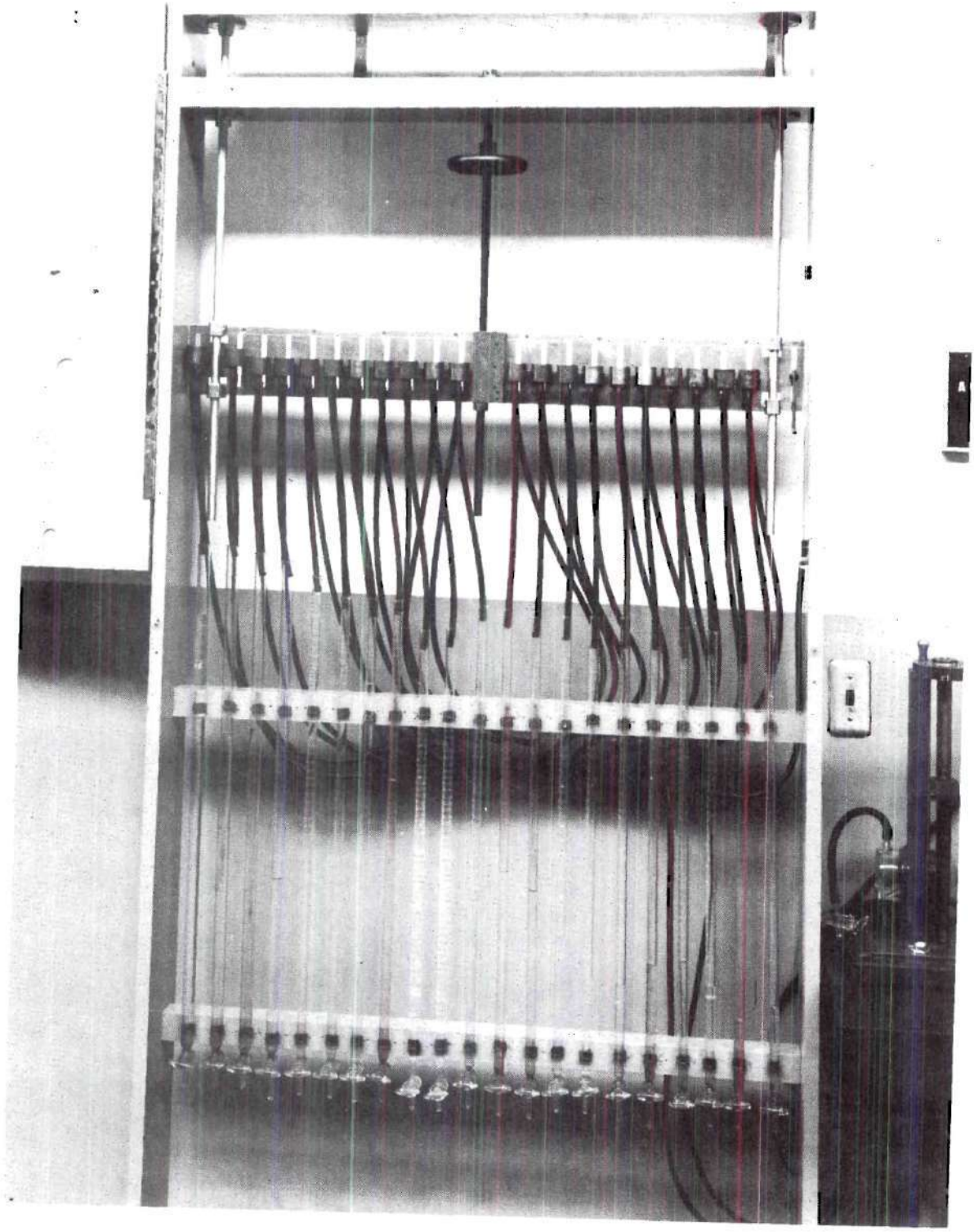


Figure 5. Condensate Collection Burrettes.

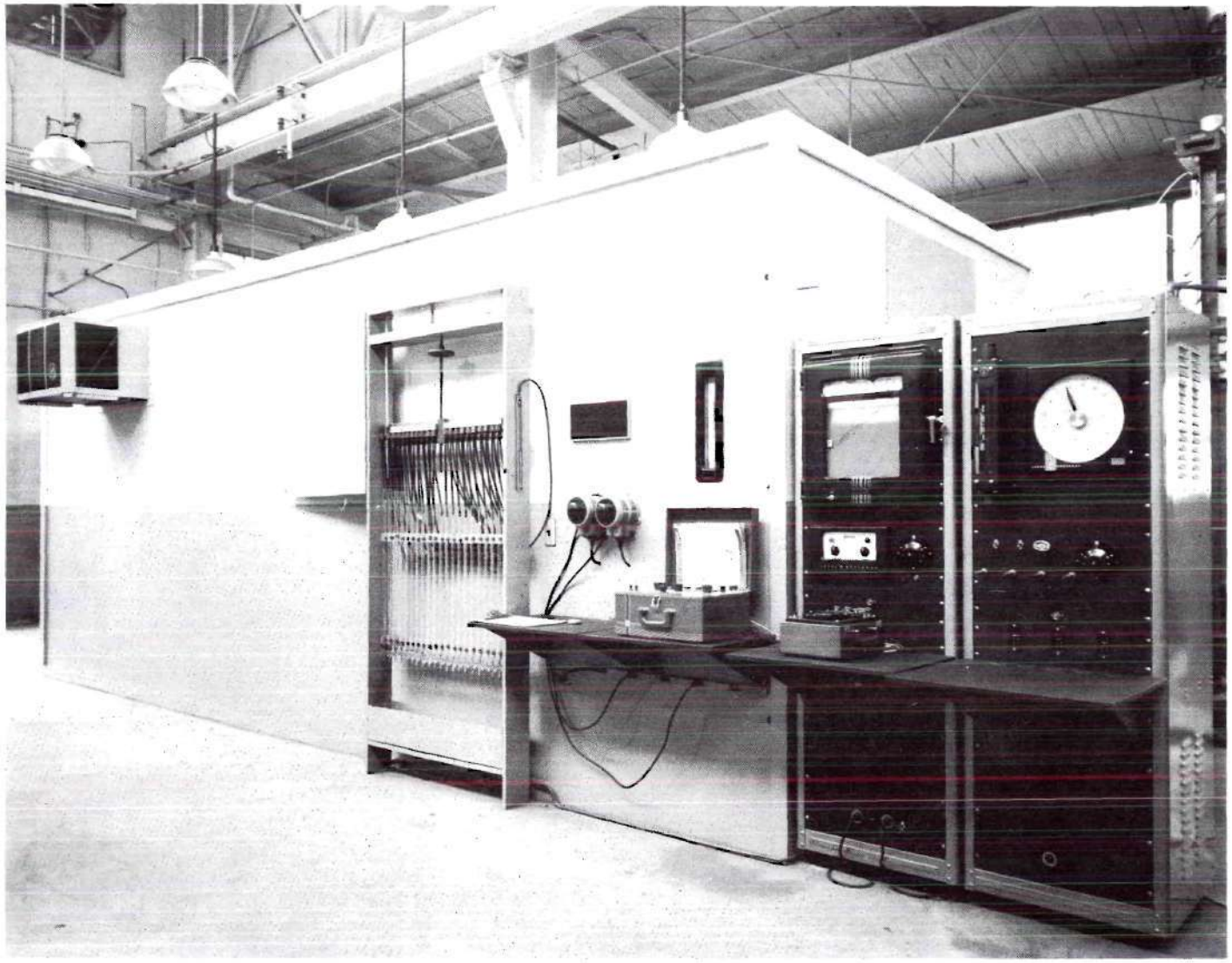


Figure 6. Temperature Measuring and Controlling Equipment.

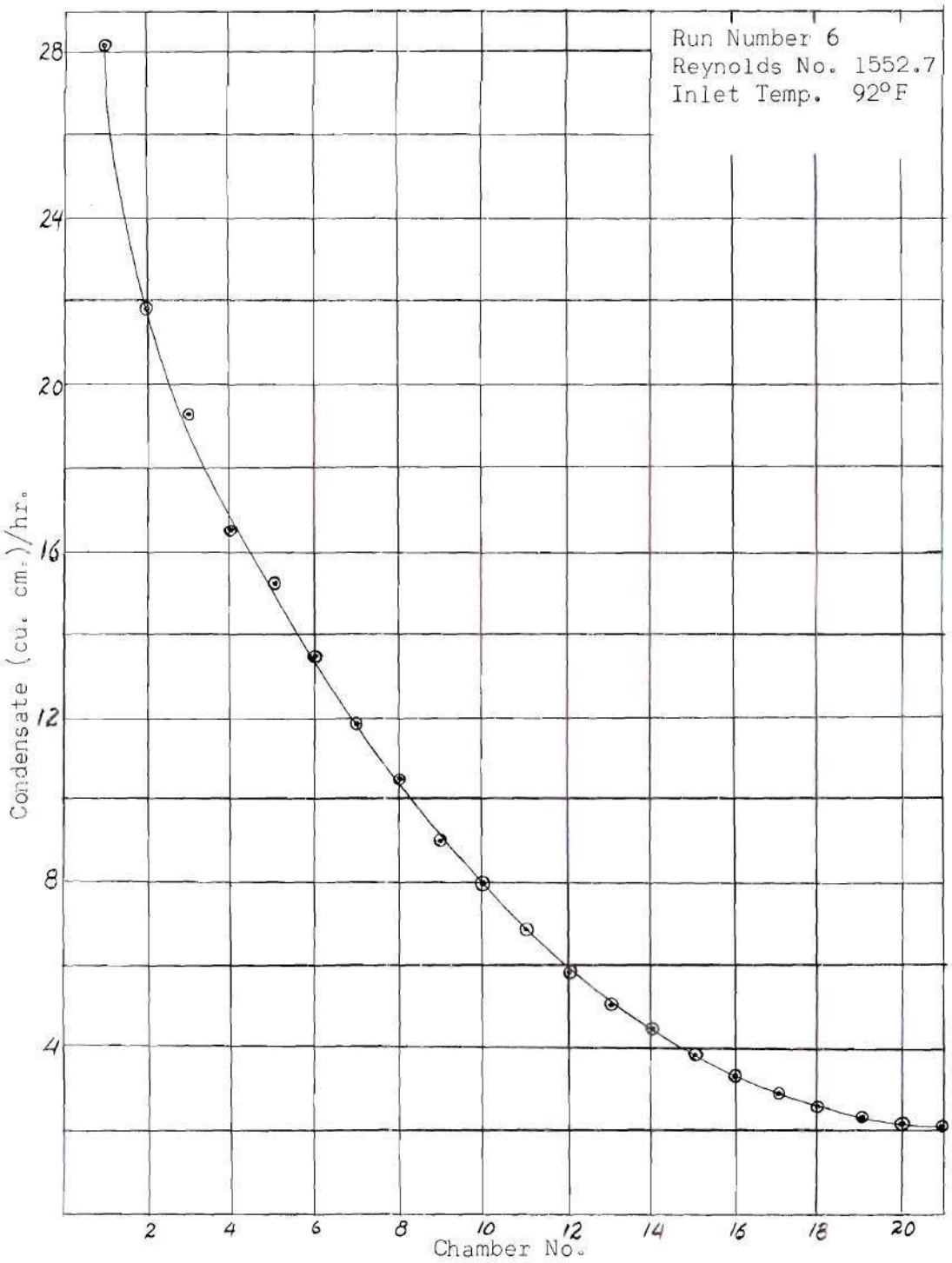


Figure 7. Typical Condensate Flow Rate

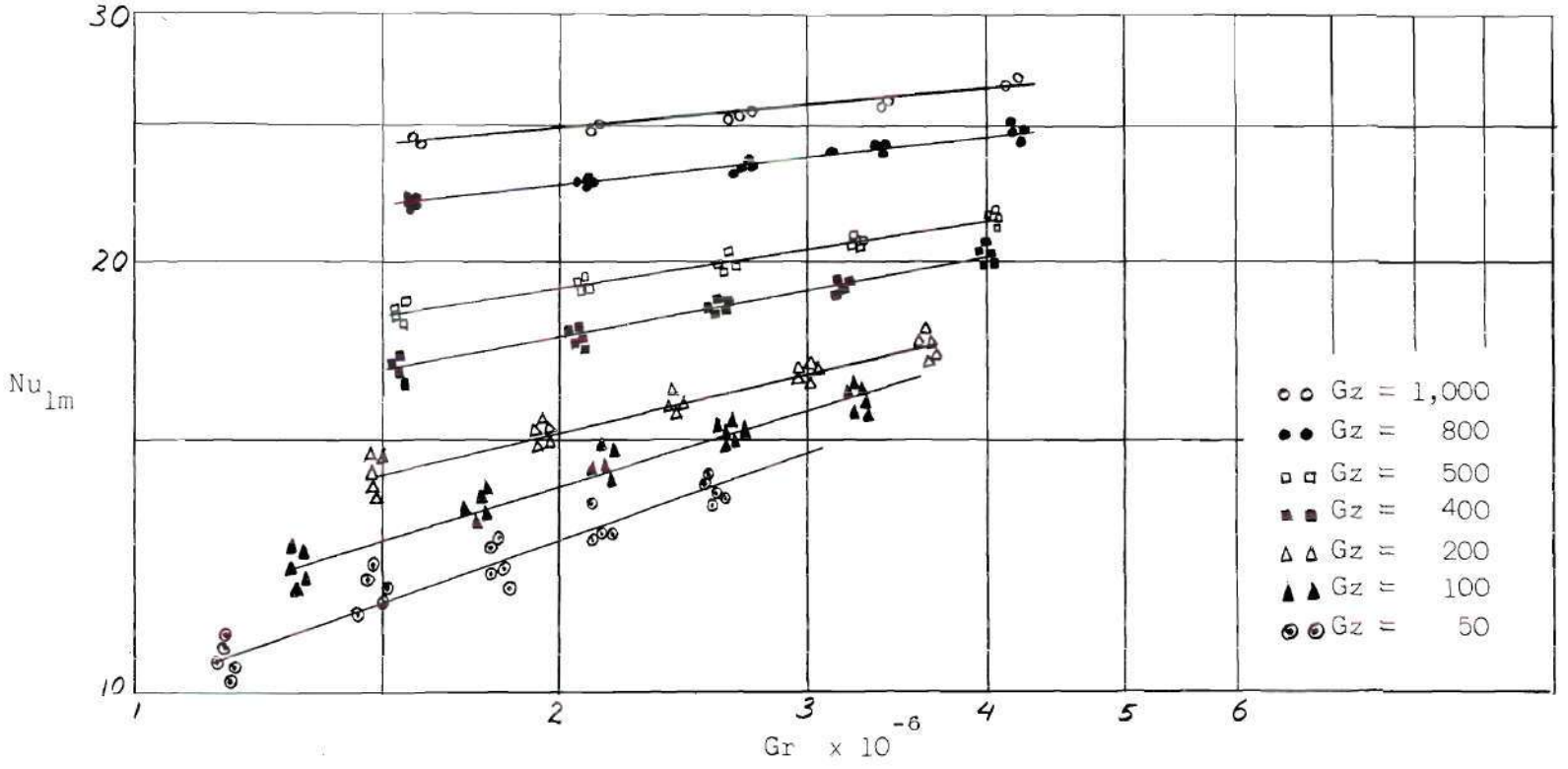


Figure 8. Effect of the Graetz and Grashof Numbers on the Average Nusselt Number

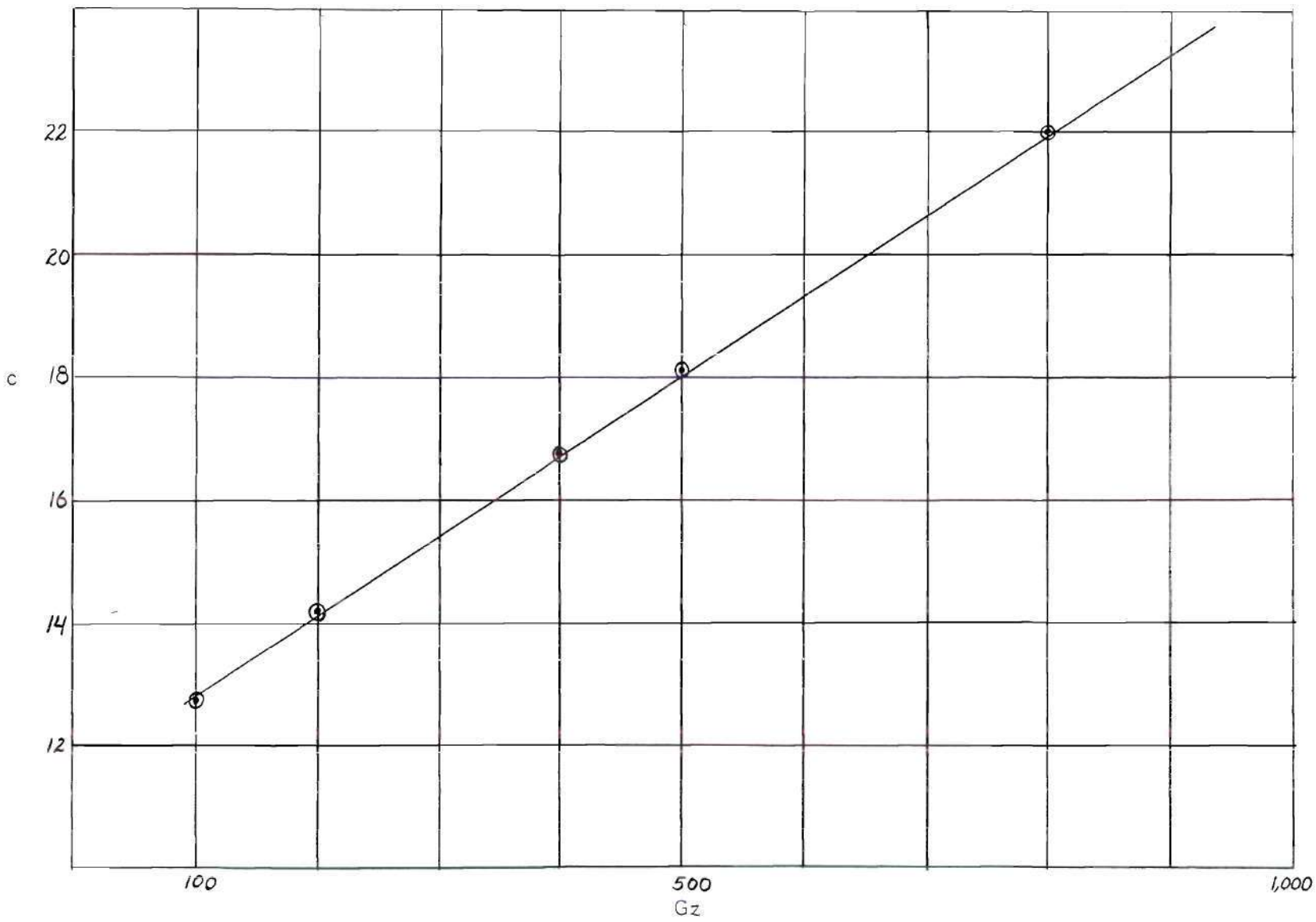


Figure 9. c Versus Graetz Number

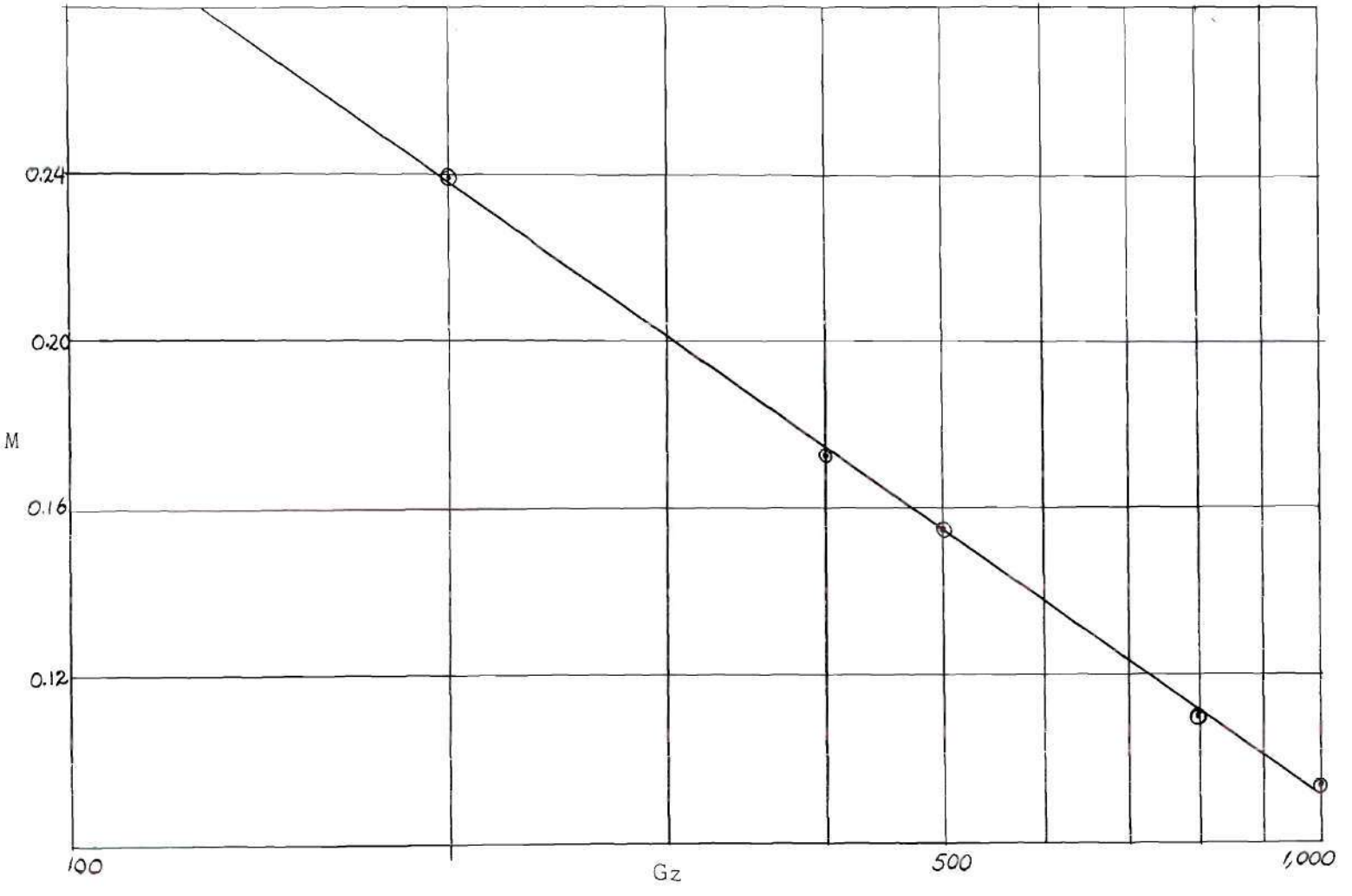


Figure 10. M Versus Graetz Number

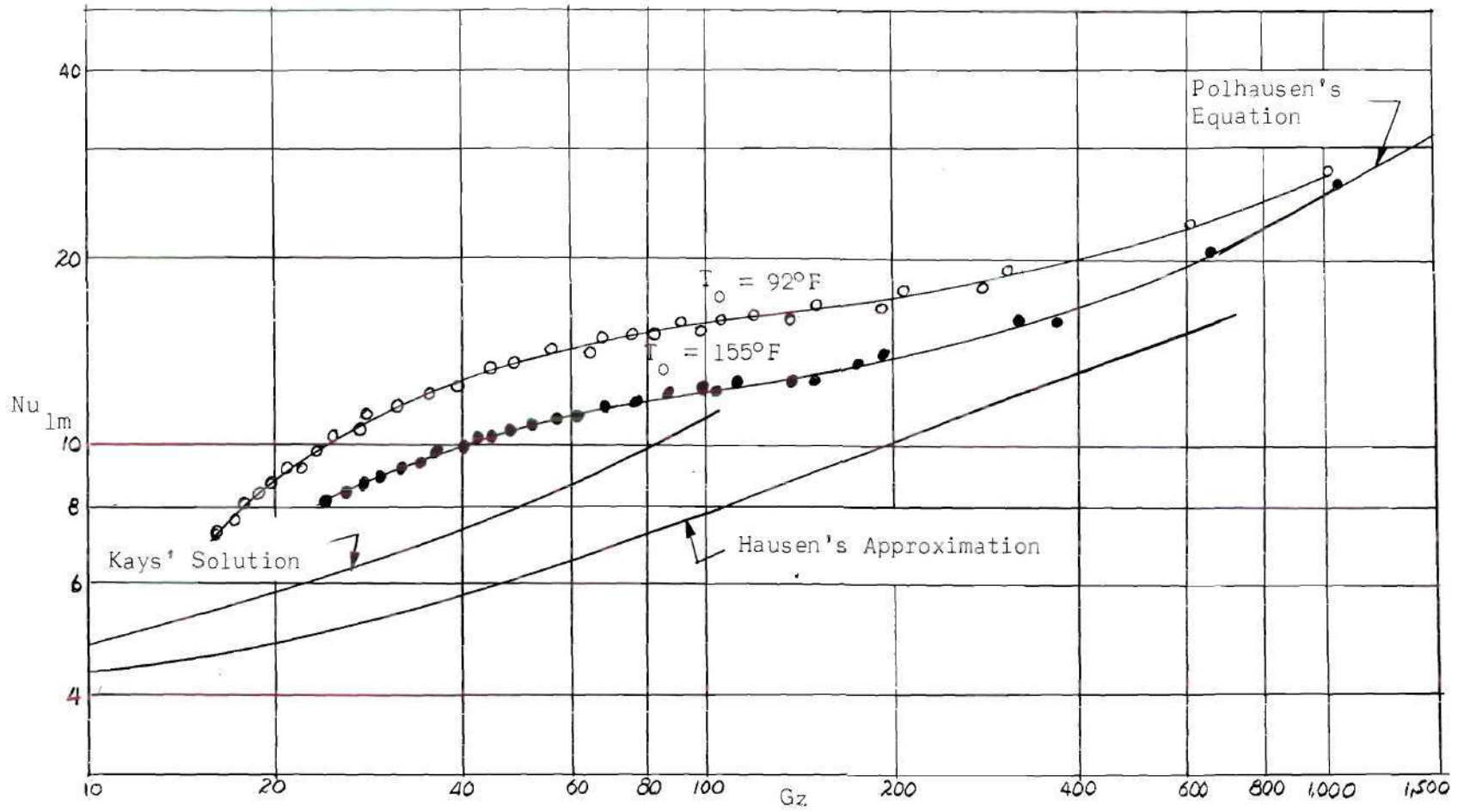


Figure 11. Average Correlations

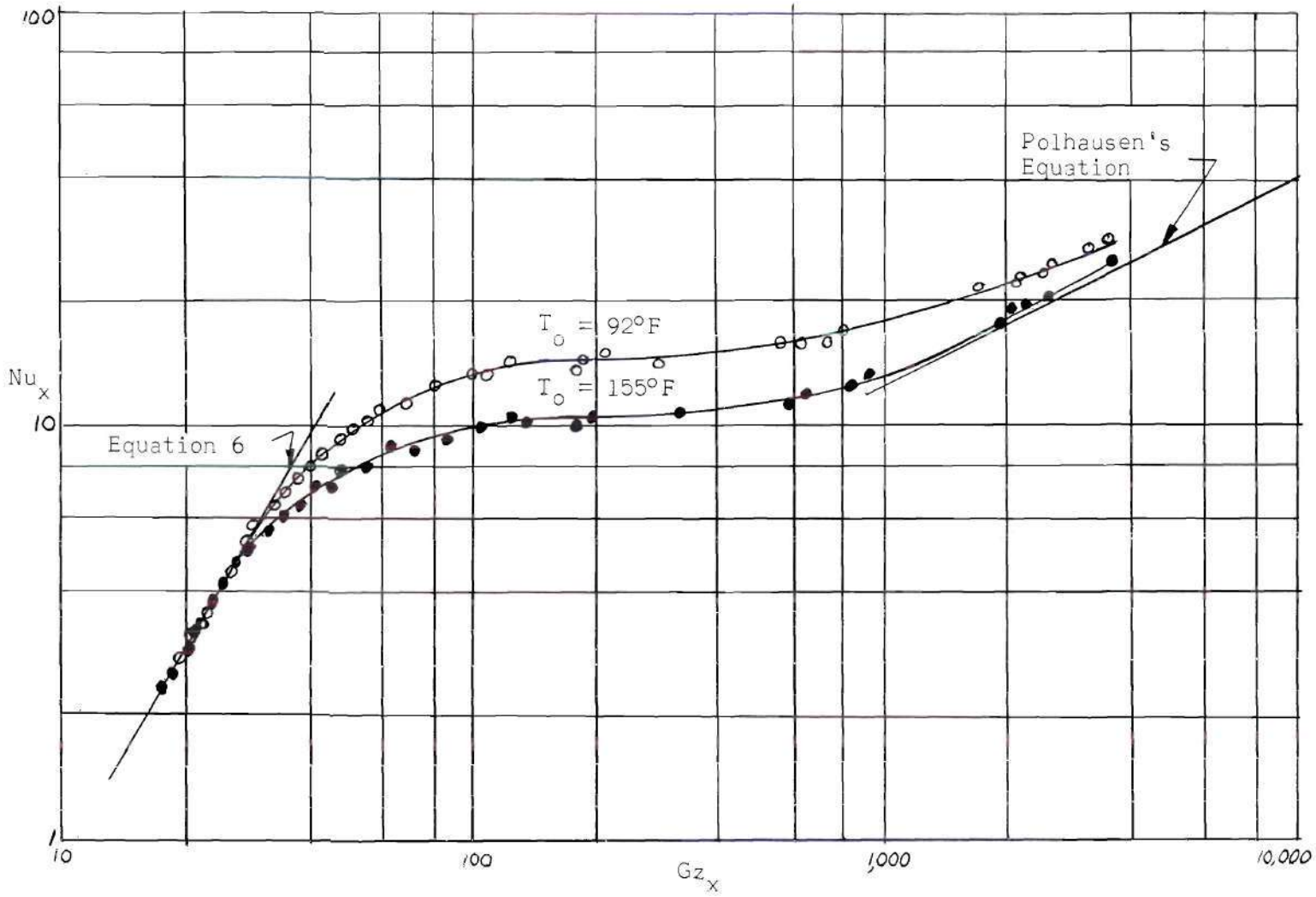


Figure 12. Local Correlations

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 1 T SUBZERO = 91.88 F
REYNOLDS NUMBER = 1741.5 T SATURATED = 210.49 F

CHAMBER	T	H	NU	GZ	GR
1	101.340	1.44222	27.3273	3078.16	4.18931
2	106.402	.930831	17.5473	703.342	3.81986
3	115.379	.882121	16.5476	363.984	3.47862
4	123.154	.823677	15.3615	220.376	3.09100
5	130.201	.822909	15.2690	157.629	2.76500
6	136.608	.813512	15.0252	122.647	2.48228
7	142.414	.796610	14.6519	100.203	2.23609
8	147.619	.767731	14.0682	84.5050	2.02237
9	152.119	.735195	13.4280	73.1627	1.84029
10	156.139	.677401	12.3371	64.3943	1.68518
11	159.712	.667043	12.1177	56.9620	1.55056
12	162.805	.612374	11.0998	51.9268	1.43513
13	165.584	.582123	10.5309	47.3372	1.33554
14	168.038	.544766	9.83808	43.4798	1.24842
15	170.183	.502271	9.05688	40.2007	1.17311
16	172.085	.472327	8.50557	37.3903	1.10779
17	173.784	.440378	7.92083	34.9517	1.05041
18	175.256	.396116	7.11729	32.8026	1.00046
19	176.452	.334340	6.00206	30.8983	.958825
20	177.610	.335207	6.01297	29.2038	.922402

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	101.340	1.44305	27.3430	1033.47	4.18690
2	106.402	1.19060	22.5192	541.652	4.05283
3	115.379	1.03668	19.5461	278.098	3.81639
4	123.154	.963746	18.1214	185.997	3.61256
5	130.201	.927124	17.3899	140.005	3.42812
6	136.608	.903101	16.9016	112.166	3.26027
7	142.414	.884129	16.5132	93.4360	3.10769
8	147.619	.866391	16.1528	79.9415	2.97019
9	152.119	.849388	15.8111	70.0563	2.85053
10	156.139	.829157	15.4132	62.0493	2.74277
11	159.712	.812477	15.0845	55.8588	2.64612
12	162.805	.793820	14.7225	50.7573	2.56164
13	165.584	.775694	14.3726	46.4871	2.48498
14	168.038	.757500	14.0237	42.8782	2.41659
15	170.183	.738887	13.6691	39.7865	2.35619
16	172.085	.720927	13.3281	37.1308	2.30208
17	173.784	.703179	12.9925	34.7997	2.25328
18	175.256	.684832	12.6471	32.7324	2.21058
19	176.452	.665125	12.2781	30.8981	2.17556
20	177.610	.647560	11.9492	29.2589	2.14140

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 2 T SUBZERO = 110.05 F
REYNOLDS NUMBER = 1770.0 T SATURATED = 210.63 F

CHAMBER	T	H	NU	GZ	GR
1	117.621	1.41350	26.4588	3165.06	3.36639
2	121.425	.851897	15.8835	724.045	3.10411
3	128.353	.823193	15.2916	375.152	2.86528
4	134.493	.779681	14.4185	227.441	2.58541
5	140.076	.775441	14.2828	162.864	2.34423
6	145.129	.756742	13.8882	126.847	2.13320
7	149.791	.747947	13.6818	103.726	1.94676
8	154.087	.735698	13.4173	87.5382	1.78004
9	157.927	.724849	13.1834	75.8302	1.63281
10	161.354	.664471	12.0560	66.7711	1.50460
11	164.331	.636285	11.5200	59.0885	1.39416
12	167.073	.618907	11.1841	53.8828	1.29752
13	169.419	.558822	10.0814	49.1335	1.21307
14	171.580	.543579	9.79183	45.1408	1.13944
15	173.424	.487599	8.77186	41.7448	1.07496
16	175.114	.472647	8.49299	38.8332	1.01878
17	176.618	.438619	7.87327	36.3055	.968566
18	177.995	.416324	7.46601	34.0765	.923723
19	179.187	.374725	6.71437	32.0993	.884110
20	180.273	.354283	6.34335	30.3398	.849276

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	117.621	1.41422	26.4723	1062.64	3.36467
2	121.425	1.13874	21.2875	557.203	3.27370
3	128.353	.981630	18.3064	286.299	3.10824
4	134.493	.912457	16.9803	191.597	2.96166
5	140.076	.876872	16.2867	144.299	2.82812
6	145.129	.851661	15.7910	115.663	2.70681
7	149.791	.833219	15.4244	96.3893	2.59433
8	154.087	.818216	15.1244	82.4957	2.48996
9	157.927	.805849	14.8763	72.3123	2.39590
10	161.354	.789090	14.5499	64.0614	2.31120
11	164.331	.773356	14.2453	57.6825	2.23691
12	167.073	.758818	13.9645	52.4214	2.16782
13	169.419	.741684	13.6383	48.0188	2.10806
14	171.580	.726012	13.3404	44.2957	2.05244
15	173.424	.708611	13.0125	41.1063	2.00451
16	175.114	.692674	12.7126	38.3655	1.96013
17	176.618	.676575	12.4108	35.9595	1.92022
18	177.995	.660974	12.1189	33.8245	1.88332
19	179.187	.644819	11.8180	31.9292	1.85109
20	180.273	.629318	11.5297	30.2361	1.82146

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 3 T SUBZERO = 124.95 F
REYNOLDS NUMBER = 1774.2 T SATURATED = 210.76 F

CHAMBER	T	H	NU	GZ	GR
1	131.251	1.40919	26.1170	3205.78	2.73978
2	134.239	.799437	14.7692	733.923	2.54300
3	139.820	.788910	14.5321	380.568	2.36666
4	144.744	.739949	13.5817	230.936	2.15705
5	149.280	.741473	13.5663	165.500	1.97437
6	153.345	.712510	12.9987	128.992	1.81313
7	157.104	.701834	12.7704	105.549	1.67036
8	160.588	.690169	12.5278	89.1301	1.54143
9	163.752	.686679	12.4369	77.2487	1.42579
10	166.626	.637712	11.5269	68.0488	1.32296
11	169.235	.636626	11.4864	60.2383	1.23135
12	171.539	.592233	10.6681	54.9463	1.15067
13	173.564	.547095	9.84101	50.1162	1.08069
14	175.386	.518635	9.31729	46.0539	1.01934
15	177.059	.499587	8.96480	42.5966	.964298
16	178.571	.477472	8.55901	39.6302	.914703
17	179.938	.449869	8.05662	37.0546	.870322
18	181.175	.422200	7.55465	34.7829	.830541
19	182.278	.391435	6.99882	32.7672	.795091
20	183.272	.366356	6.54591	30.9730	.763565

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	131.251	1.40987	26.1296	1076.31	2.73845
2	134.239	1.11205	20.5889	564.540	2.67292
3	139.820	.951402	17.5810	290.212	2.55035
4	144.744	.879217	16.2198	194.301	2.44189
5	149.280	.843528	15.5374	146.391	2.34154
6	153.345	.816252	15.0142	117.382	2.25108
7	157.104	.796112	14.6251	97.8531	2.16684
8	160.588	.779965	14.3115	83.7727	2.08811
9	163.752	.767653	14.0705	73.4494	2.01598
10	166.626	.752215	13.7742	65.0817	1.94982
11	169.235	.740152	13.5414	58.6091	1.88910
12	171.539	.726226	13.2763	53.2717	1.83491
13	173.564	.710839	12.9861	48.8033	1.78678
14	175.386	.695640	12.7007	45.0249	1.74299
15	177.059	.681255	12.4311	41.7856	1.70238
16	178.571	.667443	12.1729	39.0021	1.66527
17	179.938	.653607	11.9151	36.5579	1.63137
18	181.175	.639702	11.6567	34.3892	1.60036
19	182.278	.625651	11.3965	32.4633	1.57244
20	183.272	.611789	11.1403	30.7430	1.54704

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 4 T SUBZERO = 139.85 F
REYNOLDS NUMBER = 1781.9 T SATURATED = 210.72 F

CHAMBER	T	H	NU	GZ	GR
1	145.019	1.43215	26.2851	3249.33	2.14662
2	147.265	.743178	13.6058	744.395	2.00331
3	151.514	.739041	13.5005	386.281	1.88061
4	155.298	.695381	12.6687	234.607	1.73243
5	158.789	.693637	12.6062	168.258	1.60160
6	161.926	.664276	12.0460	131.232	1.48512
7	164.814	.647435	11.7171	107.449	1.38142
8	167.526	.640548	11.5709	90.7850	1.28689
9	170.000	.636458	11.4774	78.7222	1.20092
10	172.337	.611658	11.0126	69.3757	1.12247
11	174.431	.599903	10.7852	61.4347	1.05133
12	176.349	.576403	10.3491	56.0547	.987840
13	178.013	.524443	9.40516	51.1399	.931870
14	179.541	.505458	9.05522	47.0050	.882553
15	180.917	.476544	8.52912	43.4849	.838150
16	182.242	.484365	8.66145	40.4632	.797232
17	183.406	.442660	7.90924	37.8384	.759860
18	184.443	.408206	7.28840	35.5233	.727080
19	185.379	.382461	6.82436	33.4689	.697898
20	186.284	.384054	6.84867	31.6389	.670837

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	145.019	1.43283	26.2977	1090.94	2.14559
2	147.265	1.09794	20.1359	572.360	2.10070
3	151.514	.920173	16.8514	294.371	2.01547
4	155.298	.843731	15.4318	197.166	1.93912
5	158.789	.805122	14.7084	148.604	1.86821
6	161.926	.775999	14.1614	119.195	1.80400
7	164.814	.753608	13.7394	99.3955	1.74436
8	167.526	.736511	13.4155	85.1163	1.68785
9	170.000	.723432	13.1664	74.6454	1.63579
10	172.337	.710076	12.9132	66.1539	1.58609
11	174.431	.698582	12.6953	59.5854	1.54105
12	176.349	.686996	12.4768	54.1665	1.49936
13	178.013	.673007	12.2159	49.6294	1.46276
14	179.541	.659714	11.9685	45.7917	1.42880
15	180.917	.646266	11.7192	42.5016	1.39788
16	182.242	.635219	11.5138	39.6730	1.36777
17	183.406	.622944	11.2869	37.1895	1.34105
18	184.443	.610030	11.0491	34.9858	1.31699
19	185.379	.597136	10.8122	33.0284	1.29506
20	186.284	.585698	10.6019	31.2791	1.27363

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 5 T SUBZERO = 154.93 F
REYNOLDS NUMBER = 1791.1 T SATURATED = 210.69 F

CHAMBER	T	H	NU	GZ	GR
1	158.984	1.46120	26.5583	3293.42	1.60209
2	160.635	.709583	12.8725	754.949	1.50171
3	163.601	.666562	12.0735	392.013	1.42187
4	166.329	.643245	11.6292	238.281	1.32507
5	168.870	.643664	11.6165	171.011	1.23712
6	171.144	.610126	10.9937	133.462	1.15810
7	173.254	.595608	10.7166	109.335	1.08724
8	175.246	.588811	10.5800	92.4257	1.02188
9	177.026	.568962	10.2107	80.1831	.962579
10	178.736	.552236	9.89924	70.6945	.908375
11	180.283	.543102	9.72512	62.6271	.858352
12	181.717	.524841	9.38898	57.1623	.813059
13	183.026	.500314	8.94219	52.1651	.771772
14	184.237	.484102	8.64532	47.9580	.734170
15	185.335	.457834	8.17008	44.3753	.700019
16	186.383	.459956	8.20222	41.2994	.668520
17	187.302	.418758	7.46277	38.6270	.639834
18	188.152	.399672	7.11854	36.2688	.614194
19	188.918	.373308	6.64549	34.1753	.590909
20	189.645	.366677	6.52428	32.3104	.569517

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	158.984	1.46190	26.5709	1105.74	1.60133
2	160.635	1.09757	19.9381	580.247	1.57133
3	163.601	.885173	16.0637	298.561	1.51712
4	166.329	.803254	14.5639	200.046	1.46683
5	168.870	.762432	13.8120	150.824	1.41959
6	171.144	.731155	13.2354	121.012	1.37692
7	173.254	.707695	12.8018	100.937	1.33693
8	175.246	.689837	12.4705	86.4584	1.29879
9	177.026	.674296	12.1824	75.8405	1.26437
10	178.736	.659843	11.9145	67.2276	1.23093
11	180.283	.647757	11.6903	60.5639	1.20034
12	181.717	.636151	11.4754	55.0651	1.17169
13	183.026	.624406	11.2586	50.4588	1.14521
14	184.237	.613223	11.0526	46.5621	1.12046
15	185.335	.601773	10.8423	43.2209	1.09779
16	186.383	.592071	10.6638	40.3482	1.07590
17	187.302	.581009	10.4614	37.8256	1.05649
18	188.152	.570069	10.2615	35.5865	1.03835
19	188.918	.558894	10.0578	33.5975	1.02185
20	189.645	.548565	9.86963	31.8200	1.00604

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 6 T SUBZERO = 92.00 F
REYNOLDS NUMBER = 1552.7 T SATURATED = 210.59 F

CHAMBER	T	H	NU	GZ	GR
1	102.071	1.37312	26.0083	2743.92	4.18600
2	107.457	.889738	16.7610	626.766	3.79289
3	117.016	.848249	15.8961	324.255	3.43083
4	125.214	.789698	14.7080	196.254	3.02253
5	132.758	.806778	14.9449	140.333	2.67955
6	139.473	.786911	14.5060	109.161	2.38361
7	145.365	.750606	13.7777	89.1743	2.13311
8	150.614	.722113	13.2049	75.2010	1.92015
9	155.091	.684840	12.4824	65.1076	1.74051
10	159.036	.624198	11.3451	57.3070	1.58955
11	162.418	.593546	10.7616	50.6975	1.46159
12	165.324	.540597	9.78119	46.2221	1.35423
13	167.834	.493241	8.90837	42.1433	1.26354
14	170.060	.462228	8.33518	38.7157	1.18557
15	171.977	.418530	7.53687	35.8014	1.11837
16	173.646	.385058	6.92593	33.3036	1.06096
17	175.143	.358990	6.45032	31.1361	1.01084
18	176.447	.323588	5.80887	29.2252	.966949
19	177.610	.298912	5.36156	27.5304	.928626
20	178.704	.291446	5.22378	26.0215	.893846

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	102.071	1.37403	26.0254	921.253	4.18325
2	107.457	1.13526	21.4621	482.783	4.04027
3	117.016	.991962	18.6900	247.823	3.78792
4	125.214	.922703	17.3352	165.724	3.57243
5	132.758	.892259	16.7192	124.724	3.37437
6	139.473	.869933	16.2628	99.9136	3.19773
7	145.365	.848927	15.8377	83.2269	3.04203
8	150.614	.829772	15.4523	71.2059	2.90241
9	155.091	.811158	15.0824	62.4016	2.78236
10	159.036	.789298	14.6560	55.2710	2.67558
11	162.418	.769374	14.2694	49.7601	2.58310
12	165.324	.748194	13.8628	45.2185	2.50281
13	167.834	.726543	13.4500	41.4182	2.43272
14	170.060	.705849	13.0570	38.2059	2.36992
15	171.977	.685007	12.6631	35.4538	2.31529
16	173.646	.664899	12.2844	33.0900	2.26723
17	175.143	.645625	11.9222	31.0147	2.22375
18	176.447	.626441	11.5628	29.1740	2.18550
19	177.610	.608033	11.2186	27.5394	2.15112
20	178.704	.591195	10.9038	26.0789	2.11848

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 7 T SUBZERO = 110.00 F
REYNOLDS NUMBER = 1576.2 T SATURATED = 210.69 F

CHAMBER	T	H	NU	GZ	GR
1	118.134	1.35550	25.3680	2819.77	3.36105
2	122.331	.843653	15.7214	644.843	3.07724
3	129.916	.814187	15.1108	333.995	2.81638
4	136.502	.761960	14.0730	202.414	2.51546
5	142.566	.773503	14.2248	144.898	2.25828
6	147.981	.751456	13.7657	112.823	2.03390
7	152.915	.739720	13.5036	92.2393	1.83870
8	157.314	.708908	12.9007	77.8350	1.66828
9	161.130	.681198	12.3624	67.4236	1.52255
10	164.536	.626977	11.3511	59.3701	1.39767
11	167.467	.596854	10.7831	52.5406	1.29055
12	170.023	.550842	9.93379	47.9156	1.19962
13	172.312	.520809	9.37716	43.6960	1.12070
14	174.327	.484989	8.71985	40.1481	1.05165
15	176.063	.439470	7.89171	37.1309	.992294
16	177.608	.413744	7.42175	34.5440	.940973
17	178.963	.377768	6.76998	32.2987	.896073
18	180.212	.360266	6.45082	30.3185	.856145
19	181.282	.320754	5.73898	28.5618	.820888
20	182.209	.287808	5.14614	26.9987	.790733

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	118.134	1.35631	25.3831	946.717	3.35906
2	122.331	1.10451	20.6406	496.347	3.25856
3	129.916	.959725	17.8878	254.973	3.07720
4	136.502	.892016	16.5880	170.607	2.91967
5	142.566	.861000	15.9779	128.469	2.77425
6	147.981	.837902	15.5203	102.962	2.64373
7	152.915	.820402	15.1705	85.7972	2.52400
8	157.314	.803449	14.8347	73.4279	2.41633
9	161.130	.787610	14.5234	64.3645	2.32200
10	164.536	.768721	14.1586	57.0209	2.23690
11	167.467	.751149	13.8212	51.3441	2.16286
12	170.023	.732531	13.4669	46.6640	2.09754
13	172.312	.714455	13.1244	42.7458	2.03838
14	174.327	.696421	12.7844	39.4336	1.98568
15	176.063	.677733	12.4340	36.5956	1.93978
16	177.608	.659983	12.1021	34.1573	1.89847
17	178.963	.642172	11.7701	32.0168	1.86186
18	180.212	.625330	11.4565	30.1173	1.82781
19	181.282	.608186	11.1384	28.4309	1.79833
20	182.209	.591151	10.8231	26.9247	1.77257

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 8 T SUBZERO = 125.07 F
REYNOLDS NUMBER = 1593.5 T SATURATED = 210.74 F

CHAMBER	T	H	NU	GZ	GR
1	131.899	1.37815	25.5354	2878.06	2.72077
2	135.273	.819775	15.1364	658.690	2.50565
3	141.427	.795651	14.6434	341.446	2.31107
4	146.857	.753415	13.8117	207.122	2.08249
5	151.833	.758344	13.8534	148.387	1.88443
6	156.267	.732087	13.3315	115.623	1.71106
7	160.340	.723145	13.1313	94.5896	1.55888
8	164.168	.729093	13.2045	79.8581	1.42134
9	167.463	.694622	12.5505	69.2023	1.30039
10	170.389	.635458	11.4579	60.9574	1.19710
11	172.959	.617249	11.1094	53.9609	1.10761
12	175.233	.578144	10.3890	49.2218	1.03011
13	177.229	.536482	9.62692	44.8960	.962819
14	179.061	.521119	9.33951	41.2573	.903301
15	180.656	.478419	8.56463	38.1610	.850681
16	182.066	.448462	8.02046	35.5058	.805036
17	183.285	.404477	7.22762	33.2010	.765475
18	184.419	.390065	6.96474	31.1682	.730375
19	185.401	.351988	6.28053	29.3642	.699042
20	186.301	.334693	5.96828	27.7583	.671362

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	131.899	1.37894	25.5501	966.289	2.71921
2	135.273	1.10528	20.4558	506.761	2.64530
3	141.427	.951200	17.5671	260.459	2.51026
4	146.857	.883501	16.2866	174.351	2.39065
5	151.833	.850882	15.6588	131.341	2.28041
6	156.267	.825991	15.1778	105.301	2.18139
7	160.340	.807742	14.8220	87.7730	2.08964
8	164.168	.795451	14.5776	75.1345	2.00245
9	167.463	.782214	14.3191	65.8729	1.92652
10	170.389	.764883	13.9880	58.3674	1.85825
11	172.959	.749681	13.6982	52.5633	1.79752
12	175.233	.733638	13.3948	47.7771	1.74309
13	177.229	.716761	13.0779	43.7700	1.69467
14	179.061	.701298	12.7879	40.3812	1.64966
15	180.656	.685014	12.4843	37.4770	1.60998
16	182.066	.669056	12.1877	34.9817	1.57445
17	183.285	.652324	11.8780	32.7912	1.54337
18	184.419	.636622	11.5877	30.8470	1.51415
19	185.401	.620570	11.2918	29.1207	1.48854
20	186.301	.605326	11.0111	27.5783	1.46485

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 9 T SUBZERO = 140.02 F
REYNOLDS NUMBER = 1603.1 T SATURATED = 210.85 F

CHAMBER	T	H	NU	GZ	GR
1	145.509	1.37159	25.1659	2921.04	2.14840
2	147.984	.741873	13.5752	669.062	1.99414
3	152.596	.730564	13.3364	347.120	1.86020
4	156.647	.682214	12.4177	210.779	1.70067
5	160.399	.687745	12.4858	151.143	1.56085
6	163.757	.660440	11.9617	117.864	1.43654
7	166.868	.651930	11.7822	96.4902	1.32596
8	169.725	.635520	11.4630	81.5161	1.22604
9	172.341	.637707	11.4817	70.6784	1.13614
10	174.766	.605071	10.8760	62.2824	1.05480
11	176.875	.579122	10.3941	55.1517	.982805
12	178.760	.544878	9.76671	50.3224	.920283
13	180.498	.529090	9.47248	45.9097	.864297
14	181.960	.469243	8.39223	42.1977	.815398
15	183.288	.446623	7.98041	39.0391	.773201
16	184.481	.423505	7.56112	36.3286	.735429
17	185.583	.407550	7.27083	33.9742	.701309
18	186.568	.376865	6.71884	31.8968	.670513
19	187.389	.326305	5.81403	30.0537	.644042
20	188.143	.309950	5.51980	28.4130	.621084

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	145.509	1.37234	25.1795	980.717	2.14723
2	147.984	1.06557	19.5347	514.492	2.09754
3	152.596	.899464	16.4638	264.577	2.00454
4	156.647	.825568	15.0906	177.194	1.92232
5	160.399	.789998	14.4222	133.540	1.84555
6	163.757	.763116	13.9157	107.104	1.77621
7	166.868	.743599	13.5457	89.3065	1.71134
8	169.725	.727227	13.2348	76.4730	1.65110
9	172.341	.715439	13.0089	67.0623	1.59530
10	174.766	.702255	12.7588	59.4318	1.54294
11	176.875	.689506	12.5184	53.5305	1.49679
12	178.760	.675923	12.2640	48.6628	1.45504
13	180.498	.663241	12.0270	44.5856	1.41604
14	181.960	.647945	11.7439	41.1389	1.38281
15	183.288	.633224	11.4720	38.1838	1.35228
16	184.481	.619056	11.2109	35.6441	1.32454
17	185.583	.605626	10.9636	33.4135	1.29860
18	186.568	.591905	10.7117	31.4341	1.27518
19	187.389	.576927	10.4378	29.6766	1.25544
20	188.143	.562692	10.1778	28.1062	1.23715

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 10 T SUBZERO = 155.07 F
REYNOLDS NUMBER = 1585.6 T SATURATED = 210.57 F

CHAMBER	T	H	NU	GZ	GR
1	159.282	1.35269	24.5844	2915.58	1.58378
2	161.025	.668998	12.1345	668.281	1.47971
3	164.185	.636797	11.5316	346.978	1.39556
4	166.960	.588562	10.6371	210.889	1.29550
5	169.651	.615437	11.1027	151.343	1.20509
6	172.052	.584237	10.5222	118.101	1.12234
7	174.246	.563907	10.1407	96.7452	1.04886
8	176.268	.545828	9.80199	81.7798	.982456
9	178.110	.539919	9.68360	70.9452	.922408
10	179.830	.510440	9.14420	62.5484	.867735
11	181.432	.518684	9.28180	55.4095	.817336
12	182.851	.480131	8.58341	50.5739	.771999
13	184.129	.452158	8.07622	46.1534	.731913
14	185.296	.432183	7.71331	42.4322	.695876
15	186.346	.405844	7.23800	39.2635	.663470
16	187.295	.385667	6.87368	36.5436	.634456
17	188.088	.333269	5.93644	34.1815	.609330
18	188.814	.313628	5.58383	32.0974	.587546
19	189.484	.298936	5.31984	30.2468	.567622
20	190.098	.282718	5.02914	28.5982	.549376

TABLE _
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	159.282	1.35339	24.5972	978.885	1.58296
2	161.025	1.02173	18.5586	513.662	1.55146
3	164.185	.831843	15.0935	264.283	1.49395
4	166.960	.749672	13.5900	177.076	1.44300
5	169.651	.715152	12.9526	133.499	1.39312
6	172.052	.688150	12.4536	107.107	1.34815
7	174.246	.666617	12.0551	89.3369	1.30661
8	176.268	.648553	11.7206	76.5210	1.26792
9	178.110	.634550	11.4605	67.1222	1.23224
10	179.830	.619916	11.1899	59.4992	1.19855
11	181.432	.609387	10.9940	53.6005	1.16678
12	182.851	.597251	10.7700	48.7342	1.13832
13	184.129	.584778	10.5406	44.6580	1.11235
14	185.296	.572693	10.3188	41.2099	1.08838
15	186.346	.560465	10.0950	38.2533	1.06657
16	187.295	.548633	9.87882	35.7120	1.04663
17	188.088	.535010	9.63100	33.4807	1.02981
18	188.814	.521764	9.39030	31.5000	1.01427
19	189.484	.509182	9.16185	29.7404	.999792
20	190.098	.497096	8.94258	28.1680	.986402

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 11 T SUBZERO = 91.95 F
REYNOLDS NUMBER = 1407.7 T SATURATED = 210.86 F

CHAMBER	T	H	NU	GZ	GR
1	102.489	1.30041	24.6231	2484.47	4.22897
2	108.126	.845799	15.9242	567.361	3.81405
3	118.146	.810493	15.1762	293.450	3.43236
4	126.739	.758622	14.1136	177.559	3.00282
5	134.683	.783575	14.4953	126.931	2.64214
6	141.509	.741496	13.6479	98.7199	2.33592
7	147.392	.696813	12.7704	80.6427	2.08396
8	152.491	.652776	11.9191	68.0105	1.87450
9	156.900	.628051	11.4311	58.8870	1.69917
10	160.688	.558120	10.1306	51.8358	1.55236
11	163.827	.511996	9.27198	45.8636	1.43136
12	166.564	.471801	8.52742	41.8208	1.33088
13	168.864	.417549	7.53428	38.1353	1.24631
14	170.905	.390090	7.02872	35.0382	1.17456
15	172.611	.341517	6.14593	32.4050	1.11345
16	174.072	.307255	5.52359	30.1484	1.06241
17	175.314	.270149	4.85222	28.1906	1.01927
18	176.324	.225339	4.04439	26.4652	.983624
19	177.259	.214546	3.84822	24.9347	.953052
20	178.079	.193044	3.46054	23.5720	.925654

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	102.489	1.30134	24.6408	834.145	4.22594
2	108.126	1.07667	20.3461	437.095	4.07467
3	118.146	.943693	17.7705	224.334	3.80742
4	126.739	.880222	16.5255	149.996	3.57920
5	134.683	.854587	15.9998	112.872	3.36830
6	141.509	.830834	15.5183	90.4161	3.18664
7	147.392	.807493	15.0516	75.3160	3.02921
8	152.491	.784452	14.5964	64.4411	2.89178
9	156.900	.764510	14.2038	56.4747	2.77186
10	160.688	.740528	13.7403	50.0241	2.66782
11	163.827	.717453	13.2978	45.0401	2.58069
12	166.564	.694812	12.8660	40.9318	2.50394
13	168.864	.671368	12.4221	37.4945	2.43878
14	170.905	.649428	12.0078	34.5886	2.38039
15	172.611	.627173	11.5895	32.0995	2.33110
16	174.072	.605798	11.1890	29.9614	2.28854
17	175.314	.584731	10.7953	28.0848	2.25204
18	176.324	.563407	10.3980	26.4206	2.22215
19	177.259	.543862	10.0341	24.9423	2.19429
20	178.079	.525275	9.68852	23.6217	2.16973

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 12 T SUBZERO = 110.05 F
REYNOLDS NUMBER = 1393.0 T SATURATED = 210.91 F

CHAMBER	T	H	NU	GZ	GR
1	118.863	1.29976	24.3145	2489.99	3.37768
2	123.423	.815963	15.1935	569.223	3.06849
3	131.611	.787446	14.5983	294.731	2.78587
4	138.601	.730112	13.4653	178.558	2.46420
5	144.752	.712489	13.0818	127.801	2.19821
6	150.373	.711530	13.0123	99.5020	1.96942
7	155.325	.680484	12.4004	81.3429	1.77134
8	159.715	.650646	11.8197	68.6406	1.60195
9	163.444	.613529	11.1153	59.4613	1.45893
10	166.643	.542716	9.80981	52.3642	1.33991
11	169.411	.519010	9.36281	46.3465	1.23959
12	171.810	.475358	8.56072	42.2715	1.15431
13	173.863	.428434	7.70437	38.5540	1.08201
14	175.685	.400684	7.19618	35.4286	1.01994
15	177.231	.356144	6.38917	32.7703	.966668
16	178.584	.328302	5.88411	30.4911	.921288
17	179.737	.289860	5.19086	28.5129	.882403
18	180.745	.260432	4.66055	26.7687	.849149
19	181.622	.234028	4.18547	25.2213	.820341
20	182.429	.221821	3.96497	23.8434	.794743

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	118.863	1.30067	24.3315	835.996	3.37533
2	123.423	1.06243	19.8433	438.243	3.26526
3	131.611	.925267	17.2325	225.078	3.06787
4	138.601	.858550	15.9515	150.584	2.89923
5	144.752	.820935	15.2204	113.388	2.75028
6	150.373	.797956	14.7659	90.8698	2.61336
7	155.325	.777374	14.3606	75.7200	2.49174
8	159.715	.758333	13.9879	64.8038	2.38285
9	163.444	.739825	13.6292	56.8067	2.28933
10	166.643	.716908	13.1927	50.3291	2.20820
11	169.411	.696848	12.8115	45.3210	2.13717
12	171.810	.676387	12.4252	41.1921	2.07488
13	173.863	.655373	12.0308	37.7365	2.02096
14	175.685	.635469	11.6582	34.8147	1.97256
15	177.231	.615245	11.2813	32.3112	1.93107
16	178.584	.596036	10.9241	30.1603	1.89437
17	179.737	.576791	10.5672	28.2722	1.86280
18	180.745	.557980	10.2191	26.5970	1.83500
19	181.622	.539810	9.88345	25.1094	1.81058
20	182.429	.522937	9.57191	23.7802	1.78795

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 13 T SUBZERO = 125.15 F
REYNOLDS NUMBER = 1410.3 T SATURATED = 210.80 F

CHAMBER	T	H	NU	GZ	GR
1	132.339	1.28756	23.8517	2547.20	2.71827
2	135.961	.784031	14.4702	582.847	2.49033
3	142.487	.755332	13.8925	302.068	2.28354
4	148.219	.716381	13.1215	183.194	2.04268
5	153.403	.715944	13.0654	131.222	1.83618
6	158.014	.693409	12.6127	102.236	1.65707
7	162.163	.674357	12.2303	83.6311	1.50174
8	165.869	.647478	11.7122	70.6077	1.36624
9	169.061	.617445	11.1435	61.1910	1.25016
10	171.842	.554119	9.98091	53.9052	1.15177
11	174.278	.536103	9.63981	47.7226	1.06743
12	176.407	.495502	8.89640	43.5355	.994823
13	178.225	.445448	7.98736	39.7137	.932945
14	179.801	.406998	7.28979	36.5002	.880402
15	181.201	.379047	6.78256	33.7660	.834805
16	182.484	.366480	6.55195	31.4198	.794090
17	183.526	.309041	5.52085	29.3832	.759107
18	184.477	.290677	5.18942	27.5874	.729340
19	185.285	.255251	4.55437	25.9937	.703242
20	186.001	.233478	4.16381	24.5750	.680749

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	132.339	1.28839	23.8670	855.205	2.71653
2	135.961	1.04112	19.2625	448.466	2.63703
3	142.487	.898833	16.5928	230.468	2.49348
4	148.219	.836330	15.4089	154.260	2.36681
5	153.403	.805001	14.8055	116.197	2.25146
6	158.014	.781618	14.3530	93.1549	2.14795
7	162.163	.762729	13.9865	77.6466	2.05387
8	165.869	.745328	13.6503	66.4690	1.96883
9	169.061	.728882	13.3347	58.2777	1.89469
10	171.842	.708479	12.9493	51.6401	1.82923
11	174.278	.690919	12.6180	46.5071	1.77114
12	176.407	.672794	12.2782	42.2744	1.71969
13	178.225	.653482	11.9185	38.7312	1.67523
14	179.801	.634202	11.5608	35.7356	1.63619
15	181.201	.615688	11.2180	33.1677	1.60111
16	182.484	.598949	10.9083	30.9606	1.56860
17	183.526	.580703	10.5723	29.0236	1.54191
18	184.477	.563426	10.2545	27.3045	1.51732
19	185.285	.546121	9.93690	25.7779	1.49624
20	186.001	.529523	9.63258	24.4141	1.47739

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 14 T SUBZERO = 140.00 F
REYNOLDS NUMBER = 1404.2 T SATURATED = 210.77 F

CHAMBER	T	H	NU	GZ	GR
1	145.757	1.26503	23.2102	2561.25	2.13514
2	148.477	.719994	13.1723	586.553	1.97171
3	153.430	.696382	12.7074	304.254	1.82766
4	157.792	.656841	11.9485	184.709	1.65759
5	161.661	.637429	11.5636	132.431	1.51161
6	165.190	.626824	11.3433	103.263	1.38378
7	168.430	.616735	11.1357	84.5281	1.26954
8	171.368	.596582	10.7498	71.4057	1.16749
9	173.934	.573027	10.3067	61.9117	1.07833
10	176.173	.511659	9.18840	54.5615	1.00183
11	178.156	.497444	8.92077	48.3198	.935647
12	179.856	.448257	8.02900	44.0932	.878672
13	181.357	.414742	7.42092	40.2324	.829713
14	182.666	.379235	6.77937	36.9841	.787173
15	183.814	.347333	6.20410	34.2195	.750305
16	184.860	.332201	5.92958	31.8470	.717642
17	185.746	.290917	5.18942	29.7866	.689094
18	186.541	.268653	4.78965	27.9689	.664398
19	187.247	.245814	4.38033	26.3555	.642459
20	187.888	.230139	4.09921	24.9185	.622865

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	145.757	1.26579	23.2241	859.924	2.13386
2	148.477	.999466	18.3208	451.085	2.07938
3	153.430	.849037	15.5373	231.943	1.97972
4	157.792	.783499	14.3169	155.323	1.89126
5	161.661	.746041	13.6147	117.052	1.81210
6	165.190	.721274	13.1472	93.8756	1.73917
7	168.430	.702923	12.7988	78.2723	1.67144
8	171.368	.686861	12.4940	67.0227	1.60924
9	173.934	.672187	12.2166	58.7759	1.55422
10	176.173	.653438	11.8670	52.0915	1.50559
11	178.156	.637531	11.5705	46.9211	1.46197
12	179.856	.620004	11.2460	42.6570	1.42409
13	181.357	.602555	10.9240	39.0861	1.39023
14	182.666	.585078	10.6026	36.0664	1.36037
15	183.814	.567830	10.2861	33.4776	1.33388
16	184.860	.552013	9.99612	31.2525	1.30950
17	185.746	.535572	9.69555	29.2989	1.28866
18	186.541	.519670	9.40519	27.5649	1.26976
19	187.247	.504281	9.12453	26.0247	1.25285
20	187.888	.489713	8.85904	24.6485	1.23735

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 15 T SUBZERO = 154.98 F
REYNOLDS NUMBER = 1401.9 T SATURATED = 210.63 F

CHAMBER	T	H	NU	GZ	GR
1	159.444	1.26537	22.9958	2574.67	1.58778
2	161.265	.619242	11.2300	590.077	1.47775
3	164.637	.603622	10.9279	306.344	1.38857
4	167.671	.575074	10.3889	186.163	1.28065
5	170.464	.573586	10.3421	133.583	1.18446
6	172.993	.554871	9.98715	104.234	1.09825
7	175.258	.526890	9.46857	85.3804	1.02190
8	177.321	.505789	9.07647	72.1704	.954031
9	179.209	.503963	9.03199	62.6073	.892922
10	180.945	.470770	8.42710	55.1962	.837568
11	182.491	.457451	8.17990	48.8971	.788030
12	183.856	.422735	7.55196	44.6315	.744548
13	185.048	.384892	6.87018	40.7323	.706706
14	186.121	.362434	6.46454	37.4504	.673462
15	187.088	.339966	6.05978	34.6558	.643735
16	187.998	.336039	5.98612	32.2564	.616565
17	188.740	.283008	5.03873	30.1723	.592791
18	189.420	.266309	4.73925	28.3335	.572439
19	190.055	.256547	4.56356	26.7006	.553703
20	190.622	.236274	4.20130	25.2460	.536641

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	159.444	1.26610	23.0092	864.427	1.58685
2	161.265	.952768	17.3043	453.589	1.55381
3	164.637	.780416	14.1581	233.359	1.49220
4	167.671	.710801	12.8821	156.342	1.43621
5	170.464	.675663	12.2340	117.864	1.38413
6	172.993	.650720	11.7724	94.5596	1.33644
7	175.258	.629324	11.3768	78.8689	1.29322
8	177.321	.610929	11.0367	67.5538	1.25339
9	179.209	.597180	10.7816	59.2555	1.21647
10	180.945	.582333	10.5075	52.5256	1.18208
11	182.491	.569535	10.2713	47.3192	1.15109
12	183.856	.555869	10.0203	43.0240	1.12336
13	185.048	.541299	9.75390	39.4265	1.09888
14	186.121	.527252	9.49742	36.3835	1.07658
15	187.088	.513614	9.24880	33.7741	1.05627
16	187.998	.501633	9.03035	31.5308	1.03694
17	188.740	.487840	8.77991	29.5612	1.02103
18	189.420	.474615	8.53997	27.8128	1.00631
19	190.055	.462324	8.31708	26.2595	.992443
20	190.622	.450285	8.09899	24.8715	.979942

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 16 T SUBZERO = 92.82 F
REYNOLDS NUMBER = 1198.6 T SATURATED = 210.57 F

CHAMBER	T	H	NU	GZ	GR
1	104.271	1.22197	23.1210	2116.48	4.10470
2	110.437	.806464	15.1649	483.084	3.66272
3	121.255	.769672	14.3876	249.748	3.25954
4	130.753	.747330	13.8723	151.029	2.80525
5	139.009	.735077	13.5621	107.923	2.43192
6	145.911	.682976	12.5361	83.9270	2.12972
7	151.733	.632173	11.5539	68.5594	1.88735
8	156.770	.594669	10.8289	57.8232	1.68838
9	160.982	.555718	10.0883	50.0712	1.52444
10	164.473	.477251	8.64174	44.0833	1.39167
11	167.324	.431191	7.79130	39.0122	1.28490
12	169.638	.368980	6.65580	35.5819	1.19959
13	171.624	.332011	5.98045	32.4542	1.12969
14	173.305	.294668	5.30138	29.8253	1.07086
15	174.723	.258683	4.64924	27.5898	1.02171
16	175.924	.229290	4.11742	25.6732	.980585
17	176.965	.204546	3.67038	24.0096	.945653
18	177.830	.173731	3.11548	22.5427	.916168
19	178.598	.158325	2.83771	21.2412	.891045
20	179.258	.139075	2.49150	20.0825	.869188

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	104.271	1.22303	23.1411	710.594	4.10112
2	110.437	1.01728	19.2062	372.285	3.93856
3	121.255	.893583	16.8068	191.019	3.65494
4	130.753	.843000	15.8029	127.681	3.40676
5	139.009	.814747	15.2295	96.0704	3.19073
6	145.911	.787445	14.6840	76.9551	3.00921
7	151.733	.760710	14.1569	64.1047	2.85493
8	156.770	.736142	13.6760	54.8500	2.72013
9	160.982	.713358	13.2335	48.0727	2.60613
10	164.473	.686109	12.7128	42.5863	2.51051
11	167.324	.660514	12.2265	38.3472	2.43153
12	169.638	.633823	11.7232	34.8544	2.36670
13	171.624	.608408	11.2455	31.9310	2.31049
14	173.305	.584051	10.7891	29.4599	2.26242
15	174.723	.560612	10.3511	27.3426	2.22153
16	175.924	.538537	9.93945	25.5236	2.18659
17	176.965	.517617	9.54994	23.9266	2.15608
18	177.830	.497239	9.17127	22.5099	2.13056
19	178.598	.478281	8.81929	21.2516	2.10774
20	179.258	.460336	8.48649	20.1276	2.08804

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 17 T SUBZERO = 109.95 F
REYNOLDS NUMBER = 1195.0 T SATURATED = 210.26 F

CHAMBER	T	H	NU	GZ	GR
1	119.442	1.21159	22.6715	2135.71	3.26395
2	124.466	.783648	14.5902	488.040	2.93798
3	133.525	.766484	14.2016	252.581	2.63599
4	141.280	.722761	13.3148	152.938	2.29297
5	148.031	.707560	12.9708	109.413	2.01174
6	153.894	.679961	12.4120	85.1627	1.77781
7	158.887	.634058	11.5320	69.6146	1.58411
8	163.188	.592906	10.7502	58.7451	1.42373
9	166.799	.555117	10.0386	50.8930	1.29104
10	169.876	.489787	8.83761	44.8225	1.18158
11	172.435	.451164	8.12558	39.6760	1.09122
12	174.578	.399237	7.17923	36.1931	1.01713
13	176.391	.355247	6.37989	33.0156	.955704
14	177.922	.315031	5.65143	30.3446	.904411
15	179.217	.278227	4.98658	28.0728	.861513
16	180.316	.247415	4.43086	26.1246	.825488
17	181.258	.218664	3.91336	24.4335	.795008
18	182.082	.196020	3.50610	22.9418	.768800
19	182.773	.168755	3.01692	21.6182	.746444
20	183.370	.149312	2.66822	20.4398	.727537

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	119.442	1.21258	22.6902	717.049	3.26126
2	124.466	1.00117	18.7015	375.828	3.14302
3	133.525	.883736	16.4561	192.965	2.93001
4	141.280	.828357	15.3837	129.065	2.74724
5	148.031	.796993	14.7670	97.1653	2.58724
6	153.894	.772596	14.2862	77.8620	2.44707
7	158.887	.748621	13.8193	64.8800	2.32643
8	163.188	.725528	13.3734	55.5284	2.22118
9	166.799	.703968	12.9600	48.6779	2.13166
10	169.876	.679184	12.4907	43.1290	2.05432
11	172.435	.656223	12.0579	38.8402	1.98912
12	174.578	.632626	11.6159	35.3048	1.93382
13	176.391	.609226	11.1794	32.3457	1.88645
14	177.922	.586354	10.7541	29.8443	1.84600
15	179.217	.564132	10.3420	27.7005	1.81141
16	180.316	.543011	9.95114	25.8588	1.78178
17	181.258	.522681	9.57554	24.2417	1.75616
18	182.082	.503304	9.21799	22.8068	1.73357
19	182.773	.484583	8.87304	21.5325	1.71449
20	183.370	.466840	8.54643	20.3940	1.69792

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 18 T SUBZERO = 124.98 F
REYNOLDS NUMBER = 1194.8 T SATURATED = 210.38 F

CHAMBER	T	H	NU	GZ	GR
1	132.748	1.18573	21.9698	2157.25	2.65764
2	136.710	.736019	13.5826	493.464	2.41495
3	143.820	.711256	13.0763	255.664	2.19421
4	149.983	.672488	12.3082	154.999	1.93990
5	155.477	.668441	12.1862	110.999	1.72550
6	160.378	.655447	11.9079	86.4635	1.54113
7	164.572	.610933	11.0656	70.7209	1.38495
8	168.149	.562523	10.1625	59.7099	1.25520
9	171.189	.529971	9.55352	51.7516	1.14733
10	173.835	.475793	8.56081	45.5941	1.05654
11	176.013	.431923	7.75914	40.3701	.980858
12	177.906	.395594	7.09705	36.8341	.917950
13	179.460	.340789	6.10692	33.6061	.865346
14	180.845	.318438	5.70090	30.8915	.820972
15	182.068	.293735	5.25418	28.5809	.781961
16	183.099	.259769	4.64319	26.5987	.748520
17	183.953	.221974	3.96520	24.8782	.720753
18	184.731	.207015	3.69601	23.3604	.696868
19	185.361	.172742	3.08270	22.0135	.676357
20	185.977	.172918	3.08457	20.8139	.658280

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	132.748	1.18663	21.9865	724.282	2.65562
2	136.710	.965380	17.8627	379.766	2.56995
3	143.820	.838718	15.4814	195.124	2.41584
4	149.983	.781738	14.3993	130.584	2.28145
5	155.477	.752289	13.8310	98.3534	2.16064
6	160.378	.731907	13.4340	78.8415	2.05168
7	164.572	.710868	13.0293	65.7151	1.95730
8	168.149	.688864	12.6108	56.2576	1.87568
9	171.189	.668741	12.2298	49.3272	1.80537
10	173.835	.646372	11.8102	43.7111	1.74328
11	176.013	.624768	11.4071	39.3697	1.69149
12	177.906	.603686	11.0152	35.7894	1.64587
13	179.460	.581504	10.6049	32.7926	1.60796
14	180.845	.561022	10.2266	30.2583	1.57378
15	182.068	.541705	9.87052	28.0856	1.54325
16	183.099	.522875	9.52413	26.2189	1.51726
17	183.953	.504003	9.17774	24.5801	1.49553
18	184.731	.486368	8.85431	23.1255	1.47559
19	185.361	.468809	8.53284	21.8339	1.45928
20	185.977	.453127	8.24571	20.6795	1.44325

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 19 T SUBZERO = 139.87 F
REYNOLDS NUMBER = 1196.2 T SATURATED = 210.47 F

CHAMBER	T	H	NU	GZ	GR
1	146.200	1.19216	21.8753	2180.46	2.09607
2	149.223	.690783	12.6354	499.199	1.91834
3	154.764	.678333	12.3719	258.865	1.76034
4	159.528	.631604	11.4800	157.103	1.57603
5	163.930	.646633	11.7173	112.603	1.41728
6	167.647	.595467	10.7611	87.7817	1.28066
7	170.979	.576672	10.3972	71.8492	1.16502
8	174.017	.565125	10.1676	60.6915	1.06283
9	176.534	.518337	9.30881	52.6214	.975474
10	178.766	.472345	8.46963	46.3751	.902082
11	180.605	.428881	7.68004	41.0720	.840103
12	182.196	.390074	6.97728	37.4826	.788538
13	183.590	.358717	6.41015	34.2031	.744144
14	184.842	.338096	6.03645	31.4434	.705167
15	185.859	.287147	5.12300	29.0948	.672021
16	186.794	.276736	4.93412	27.0797	.643703
17	187.533	.225789	4.02358	25.3299	.619579
18	188.234	.219732	3.91379	23.7861	.598933
19	188.859	.202038	3.59710	22.4152	.579998
20	189.410	.182740	3.25226	21.1942	.563286

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	146.200	1.19304	21.8914	732.075	2.09453
2	149.223	.947694	17.3717	383.981	2.03461
3	154.764	.813766	14.8889	197.400	1.92415
4	159.528	.751649	13.7303	132.173	1.82826
5	163.930	.724274	13.2107	99.5886	1.73865
6	167.647	.697694	12.7100	79.8647	1.66203
7	170.979	.676697	12.3138	66.5881	1.59238
8	174.017	.659941	11.9967	57.0160	1.52793
9	176.534	.641945	11.6597	50.0014	1.47369
10	178.766	.622220	11.2930	44.3150	1.42490
11	180.605	.602700	10.9321	39.9184	1.38408
12	182.196	.583118	10.5713	36.2920	1.34829
13	183.590	.564125	10.2222	33.2551	1.31650
14	184.842	.546475	9.89829	30.6865	1.28761
15	185.859	.527731	9.55556	28.4851	1.26384
16	186.794	.510936	9.24858	26.5928	1.24176
17	187.533	.493041	8.92247	24.9317	1.22414
18	188.234	.476794	8.62644	23.4569	1.20727
19	188.859	.461381	8.34584	22.1469	1.19208
20	189.410	.446602	8.07703	20.9764	1.17862

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 20 T SUBZERO = 155.05 F
REYNOLDS NUMBER = 1201.2 T SATURATED = 210.57 F

CHAMBER	T	H	NU	GZ	GR
1	159.833	1.16774	21.2193	2205.35	1.57421
2	161.788	.575478	10.4336	505.359	1.45682
3	165.560	.588156	10.6432	262.315	1.35909
4	168.689	.520056	9.38939	159.382	1.24377
5	171.747	.553966	9.98119	114.352	1.14264
6	174.377	.512843	9.22295	89.2184	1.05149
7	176.719	.486531	8.73547	73.0761	.973217
8	178.858	.470672	8.43831	61.7668	.903801
9	180.747	.454430	8.13638	53.5810	.842286
10	182.388	.401269	7.17627	47.2399	.789068
11	183.844	.388913	6.94828	41.8515	.742900
12	185.077	.343946	6.13952	38.2033	.703187
13	186.160	.314290	5.60593	34.8684	.669284
14	187.124	.291979	5.20451	32.0613	.639540
15	187.997	.274507	4.89014	29.6708	.613022
16	188.764	.252523	4.49612	27.6187	.589484
17	189.440	.228986	4.07514	25.8359	.568880
18	190.043	.209512	3.72703	24.2626	.550701
19	190.595	.196744	3.49859	22.8655	.534361
20	191.100	.185342	3.29471	21.6209	.519470

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	159.833	1.16853	21.2336	740.433	1.57315
2	161.788	.881187	16.0017	388.508	1.53774
3	165.560	.736160	13.3513	199.850	1.46888
4	168.689	.663198	12.0155	133.888	1.41113
5	171.747	.634991	11.4928	100.928	1.35402
6	174.377	.609873	11.0286	80.9692	1.30424
7	176.719	.588633	10.6362	67.5319	1.25933
8	178.858	.571089	10.3119	57.8418	1.21776
9	180.747	.556221	10.0372	50.7366	1.18052
10	182.388	.538229	9.70727	44.9756	1.14776
11	183.844	.523092	9.42972	40.5188	1.11829
12	185.077	.506577	9.12829	36.8425	1.09301
13	186.160	.490295	8.83173	33.7631	1.07057
14	187.124	.474811	8.55010	31.1583	1.05035
15	187.997	.460293	8.28628	28.9245	1.03187
16	188.764	.446373	8.03367	27.0046	1.01544
17	189.440	.432693	7.78572	25.3183	1.00085
18	190.043	.419406	7.54515	23.8215	.987705
19	190.595	.406895	7.31875	22.4917	.975601
20	191.100	.395122	7.10580	21.3033	.964419

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 21 T SUBZERO = 92.00 F
REYNOLDS NUMBER = 999.5 T SATURATED = 210.99 F

CHAMBER	T	H	NU	GZ	GR
1	105.291	1.17600	22.2430	1759.25	4.17786
2	112.560	.799452	15.0121	401.135	3.65637
3	125.114	.763409	14.2368	207.180	3.18500
4	135.762	.731447	13.5323	125.166	2.67006
5	144.793	.715643	13.1514	89.3862	2.26258
6	152.177	.662019	12.0987	69.4840	1.94210
7	158.300	.612360	11.1405	56.7476	1.69103
8	163.326	.553764	10.0371	47.8575	1.49207
9	167.350	.499928	9.03417	41.4451	1.33589
10	170.643	.426383	7.68650	36.4940	1.21301
11	173.290	.381187	6.85831	32.3006	1.11545
12	175.437	.327090	5.87572	29.4644	1.03811
13	177.122	.269499	4.83510	26.8788	.977188
14	178.585	.245199	4.39459	24.7058	.927719
15	179.789	.209931	3.75921	22.8574	.886223
16	180.761	.177118	3.16938	21.2727	.852642
17	181.618	.160315	2.86700	19.8970	.824601
18	182.340	.137915	2.46513	18.6835	.800536
19	183.010	.131132	2.34282	17.6062	.779424
20	183.597	.117632	2.10077	16.6467	.760441

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	105.291	1.17737	22.2690	590.656	4.17298
2	112.560	.990091	18.6788	309.329	3.97766
3	125.114	.876739	16.4677	158.620	3.64226
4	135.762	.826621	15.4688	105.983	3.35834
5	144.793	.797730	14.8814	79.7239	3.11654
6	152.177	.769732	14.3225	63.8509	2.91706
7	158.300	.742709	13.7906	53.1835	2.74963
8	163.326	.714940	13.2521	45.5059	2.61021
9	167.350	.688004	12.7352	39.8859	2.49685
10	170.643	.657933	12.1649	35.3363	2.40267
11	173.290	.630237	11.6422	31.8212	2.32581
12	175.437	.602537	11.1224	28.9246	2.26263
13	177.122	.574578	10.6002	26.5012	2.21243
14	178.585	.549059	10.1243	24.4523	2.16834
15	179.789	.524675	9.67078	22.6965	2.13171
16	180.761	.501563	9.24172	21.1883	2.10185
17	181.618	.480220	8.84589	19.8638	2.07533
18	182.340	.459958	8.47057	18.6886	2.05282
19	183.010	.441578	8.13023	17.6445	2.03180
20	183.597	.424449	7.81329	16.7117	2.01325

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 22 T SUBZERO = 109.88 F
REYNOLDS NUMBER = 1042.7 T SATURATED = 210.75 F

CHAMBER	T	H	NU	GZ	GR
1	120.377	1.16911	21.8627	1863.44	3.32046
2	126.058	.780433	14.5128	425.580	2.95206
3	136.061	.753606	13.9386	220.137	2.61277
4	144.573	.716381	13.1668	133.218	2.23379
5	151.997	.713506	13.0435	95.2615	1.92541
6	158.117	.659786	12.0067	74.1252	1.67569
7	163.150	.599905	10.8765	60.5871	1.47826
8	167.438	.558668	10.0975	51.1274	1.31881
9	170.925	.509711	9.18903	44.2961	1.18954
10	173.819	.439336	7.90366	39.0167	1.08592
11	176.192	.399570	7.17582	34.5413	1.00205
12	178.115	.342249	6.13774	31.5135	.934733
13	179.769	.309264	5.53971	28.7506	.879420
14	181.117	.264603	4.73508	26.4277	.833514
15	182.205	.222205	3.97320	24.4523	.796608
16	183.166	.205393	3.67012	22.7580	.765792
17	183.948	.171767	3.06754	21.2869	.739739
18	184.622	.151208	2.69909	19.9894	.718101
19	185.224	.138416	2.46973	18.8376	.699223
20	185.764	.126857	2.26265	17.8117	.682407

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	120.377	1.17029	21.8847	625.637	3.31712
2	126.058	.977498	18.2434	327.842	3.18083
3	136.061	.865459	16.0966	168.272	2.94094
4	144.573	.814083	15.0968	112.521	2.73609
5	151.997	.787718	14.5707	84.6911	2.55597
6	158.117	.761237	14.0515	67.8603	2.40574
7	163.150	.733564	13.5175	56.5454	2.28049
8	167.438	.707788	13.0235	48.3955	2.17215
9	170.925	.682907	12.5508	42.4269	2.08262
10	173.819	.654859	12.0235	37.5930	2.00713
11	176.192	.629261	11.5442	33.8568	1.94430
12	178.115	.603004	11.0554	30.7774	1.89264
13	179.769	.578282	10.5962	28.1993	1.84763
14	181.117	.553954	10.1458	26.0202	1.81050
15	182.205	.530087	9.70514	24.1529	1.78023
16	183.166	.508468	9.30630	22.5481	1.75321
17	183.948	.487400	8.91836	21.1392	1.73105
18	184.622	.467490	8.55210	19.8889	1.71180
19	185.224	.449092	8.21386	18.7782	1.69448
20	185.764	.432048	7.90069	17.7857	1.67888

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 23 T SUBZERO = 125.00 F
REYNOLDS NUMBER = 995.2 T SATURATED = 211.01 F

CHAMBER	T	H	NU	GZ	GR
1	133.645	1.09490	20.2718	1792.35	2.72119
2	138.066	.687363	12.6696	409.809	2.44547
3	146.012	.671907	12.3328	212.230	2.19506
4	152.950	.649345	11.8589	128.598	1.90681
5	159.073	.649362	11.8075	92.0510	1.66520
6	164.096	.592693	10.7371	71.6866	1.46709
7	168.249	.537528	9.70813	58.6336	1.30942
8	171.736	.489243	8.81378	49.5072	1.18177
9	174.604	.447296	8.04125	42.9128	1.07806
10	177.055	.394358	7.07719	37.8118	.992943
11	179.034	.351141	6.29246	33.4840	.923189
12	180.653	.301649	5.39921	30.5560	.867302
13	182.133	.288771	5.16347	27.8815	.819715
14	183.336	.245756	4.39048	25.6315	.778920
15	184.353	.216271	3.86094	23.7173	.745439
16	185.241	.197261	3.51938	22.0750	.716900
17	186.009	.175510	3.12962	20.6487	.692251
18	186.638	.146944	2.61907	19.3905	.671565
19	187.156	.123891	2.20735	18.2740	.654650
20	187.655	.122139	2.17542	17.2794	.639701

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	133.645	1.09593	20.2907	601.768	2.71865
2	138.066	.895143	16.5482	315.479	2.62066
3	146.012	.783730	14.4493	162.047	2.44398
4	152.950	.737373	13.5626	108.420	2.28853
5	159.073	.714220	13.1095	81.6427	2.14978
6	164.096	.689114	12.6272	65.4435	2.03441
7	168.249	.663145	12.1343	54.5486	1.93758
8	171.736	.637600	11.6532	46.6998	1.85499
9	174.604	.613744	11.2063	40.9493	1.78602
10	177.055	.588480	10.7362	36.2894	1.72614
11	179.034	.564700	10.2955	32.6874	1.67708
12	180.653	.540645	9.85165	29.7176	1.63643
13	182.133	.519426	9.46030	27.2299	1.59879
14	183.336	.498188	9.06985	25.1270	1.56785
15	184.353	.477886	8.69726	23.3244	1.54138
16	185.241	.459186	8.35446	21.7753	1.51807
17	186.009	.441416	8.02909	20.4148	1.49773
18	186.638	.423968	7.71009	19.2077	1.48094
19	187.156	.407192	7.40373	18.1355	1.46701
20	187.655	.392109	7.12830	17.1773	1.45350

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 24 T SUBZERO = 155.00 F
REYNOLDS NUMBER = 2006.4 T SATURATED = 210.72 F

CHAMBER	T	H	NU	GZ	GR
1	158.745	1.50994	27.4451	3692.38	1.60814
2	160.261	.726012	13.1730	846.528	1.51531
3	162.964	.673569	12.2043	439.624	1.44204
4	165.451	.646085	11.6862	267.265	1.35333
5	167.779	.645967	11.6654	191.841	1.27238
6	169.851	.605197	10.9132	149.738	1.19953
7	171.773	.586555	10.5631	122.685	1.13432
8	173.572	.570914	10.2689	103.723	1.07435
9	175.239	.568431	10.2126	89.9935	1.01918
10	176.768	.523392	9.39355	79.3515	.968853
11	178.192	.525722	9.42624	70.3031	.922822
12	179.480	.492090	8.81539	64.1740	.880971
13	180.675	.472823	8.46335	58.5687	.842994
14	181.795	.460558	8.23757	53.8487	.807865
15	182.857	.453417	8.10408	49.8279	.774995
16	183.818	.428899	7.66081	46.3758	.744731
17	184.691	.401674	7.17023	43.3767	.717481
18	185.516	.389503	6.94913	40.7295	.692412
19	186.243	.354415	6.31994	38.3793	.669618
20	186.953	.356411	6.35256	36.2856	.648614

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	158.745	1.51055	27.4562	1239.69	1.60749
2	160.261	1.13075	20.5425	650.566	1.57992
3	162.964	.905606	16.4373	334.772	1.53054
4	165.451	.817871	14.8326	224.327	1.48479
5	167.779	.774012	14.0263	169.143	1.44162
6	169.851	.739485	13.3914	135.719	1.40289
7	171.773	.713161	12.9064	113.211	1.36666
8	173.572	.691987	12.5158	96.9779	1.33247
9	175.239	.676116	12.2220	85.0713	1.30052
10	176.768	.658226	11.8925	75.4145	1.27093
11	178.192	.644600	11.6409	67.9420	1.24314
12	179.480	.630349	11.3786	61.7763	1.21779
13	180.675	.616820	11.1300	56.6108	1.19405
14	181.795	.604429	10.9024	52.2406	1.17161
15	182.857	.593294	10.6978	48.4924	1.15013
16	183.818	.582119	10.4930	45.2707	1.13053
17	184.691	.570624	10.2828	42.4410	1.11257
18	185.516	.559702	10.0832	39.9289	1.09547
19	186.243	.548064	9.87125	37.6977	1.08027
20	186.953	.537770	9.68357	35.7035	1.06531

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 25 T SUBZERO = 139.87 F
REYNOLDS NUMBER = 2010.3 T SATURATED = 210.41 F

CHAMBER	T	H	NU	GZ	GR
1	144.634	1.49247	27.4014	3667.91	2.12026
2	146.706	.771535	14.1324	840.451	1.98944
3	150.454	.729731	13.3405	436.225	1.88035
4	153.907	.704725	12.8522	265.013	1.74823
5	157.033	.684697	12.4595	190.109	1.63026
6	159.862	.655380	11.9023	148.307	1.52565
7	162.454	.630193	11.4242	121.453	1.43220
8	164.884	.617483	11.1751	102.636	1.34711
9	167.113	.611248	11.0452	89.0144	1.26944
10	169.171	.568749	10.2627	78.4592	1.19904
11	171.094	.576360	10.3863	69.4884	1.13454
12	172.843	.545242	9.81371	63.4100	1.07581
13	174.466	.526666	9.46885	57.8541	1.02252
14	175.955	.504372	9.05875	53.1775	.973880
15	177.282	.468044	8.39851	49.1964	.930297
16	178.480	.442282	7.92968	45.7803	.891575
17	179.542	.405328	7.26175	42.8137	.857189
18	180.542	.391898	7.01640	40.1959	.826034
19	181.394	.344405	6.16238	37.8727	.798247
20	182.233	.349265	6.24589	35.8036	.773032

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	144.634	1.49307	27.4125	1231.47	2.11940
2	146.706	1.14275	20.9660	646.129	2.07851
3	150.454	.938754	17.2013	332.368	2.00429
4	153.907	.859222	15.7257	222.640	1.93558
5	157.033	.814626	14.8938	167.825	1.87303
6	159.862	.781886	14.2816	134.626	1.81604
7	162.454	.755693	13.7912	112.273	1.76348
8	164.884	.735029	13.4031	96.1533	1.71383
9	167.113	.719076	13.1024	84.3316	1.66794
10	169.171	.701405	12.7716	74.7451	1.62522
11	171.094	.688465	12.5279	67.3273	1.58495
12	172.843	.675003	12.2758	61.2077	1.54802
13	174.466	.662194	12.0363	56.0815	1.51344
14	175.955	.649647	11.8024	51.7455	1.48144
15	177.282	.636316	11.5551	48.0284	1.45267
16	178.480	.623172	11.3118	44.8339	1.42649
17	179.542	.609347	11.0570	42.0287	1.40307
18	180.542	.596283	10.8163	39.5386	1.38086
19	181.394	.582057	10.5553	37.3276	1.36180
20	182.233	.569601	10.3245	35.3514	1.34290

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 26 T SUBZERO = 125.05 F
REYNOLDS NUMBER = 1995.2 T SATURATED = 210.22 F

CHAMBER	T	H	NU	GZ	GR
1	130.841	1.46344	27.1354	3607.13	2.67460
2	133.540	.812051	15.0134	826.029	2.49816
3	138.546	.790995	14.5857	428.453	2.34218
4	142.986	.739788	13.5977	260.086	2.15622
5	147.016	.724179	13.2727	186.451	1.99428
6	150.626	.689237	12.5998	145.368	1.85200
7	153.929	.664585	12.1209	118.984	1.72631
8	157.001	.648755	11.8070	100.503	1.61292
9	159.861	.655036	11.8977	87.1264	1.50953
10	162.495	.610949	11.0766	76.7634	1.41556
11	164.853	.595308	10.7751	67.9631	1.33165
12	166.958	.554302	10.0181	62.0013	1.25782
13	168.897	.532374	9.60892	56.5560	1.19186
14	170.587	.484893	8.74144	51.9752	1.13342
15	172.148	.466268	8.39665	48.0769	1.08166
16	173.553	.439842	7.91302	44.7319	1.03494
17	174.810	.406841	7.31292	41.8275	.993405
18	175.994	.393970	7.07588	39.2651	.955640
19	177.021	.353058	6.33648	36.9911	.921705
20	177.988	.342883	6.14984	34.9666	.891309

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	130.841	1.46404	27.1466	1211.06	2.67350
2	133.540	1.14635	21.2362	635.279	2.61559
3	138.546	.970034	17.9391	326.640	2.50806
4	142.986	.891638	16.4643	218.727	2.41246
5	147.016	.848682	15.6496	164.822	2.32538
6	150.626	.815839	15.0254	132.180	2.24701
7	153.929	.789662	14.5270	110.206	2.17494
8	157.001	.768570	14.1243	94.3615	2.10750
9	159.861	.753815	13.8397	82.7417	2.04427
10	162.495	.736941	13.5178	73.3211	1.98560
11	164.853	.722345	13.2395	66.0345	1.93267
12	166.958	.706633	12.9424	60.0248	1.88506
13	168.897	.691662	12.6599	54.9915	1.84083
14	170.587	.675369	12.3546	50.7362	1.80197
15	172.148	.660075	12.0685	47.0877	1.76579
16	173.553	.645200	11.7909	43.9525	1.73299
17	174.810	.630097	11.5101	41.1996	1.70340
18	175.994	.615931	11.2468	38.7561	1.67534
19	177.021	.601089	10.9720	36.5866	1.65082
20	177.988	.587297	10.7168	34.6480	1.62756

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 27 T SUBZERO = 110.00 F
REYNOLDS NUMBER = 1990.8 T SATURATED = 210.43 F

CHAMBER	T	H	NU	GZ	GR
1	116.982	1.46555	27.4435	3565.13	3.34638
2	120.417	.860381	16.0530	815.834	3.10749
3	126.722	.832592	15.4824	422.854	2.89125
4	132.269	.776328	14.3774	256.466	2.63710
5	137.346	.770057	14.2096	183.716	2.41741
6	141.920	.740973	13.6280	143.134	2.22433
7	146.131	.723753	13.2718	117.079	2.05376
8	150.083	.717714	13.1248	98.8334	1.89959
9	153.669	.710806	12.9656	85.6310	1.76086
10	156.854	.642708	11.6969	75.4128	1.63915
11	159.706	.628795	11.4206	66.7435	1.53291
12	162.185	.572342	10.3768	60.8707	1.44084
13	164.397	.533158	9.65135	55.5124	1.36115
14	166.439	.515582	9.32002	51.0053	1.28997
15	168.222	.469849	8.48256	47.1706	1.22682
16	169.836	.446411	8.05036	43.8823	1.17140
17	171.304	.420323	7.57220	41.0272	1.12167
18	172.631	.391276	7.04241	38.5092	1.07701
19	173.831	.365829	6.57894	36.2752	1.03700
20	174.922	.343684	6.17603	34.2865	1.00101

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	116.982	1.46618	27.4554	1196.96	3.34493
2	120.417	1.16996	21.8822	627.714	3.26347
3	126.722	1.00217	18.7031	322.598	3.11418
4	132.269	.925117	17.2318	215.933	2.98292
5	137.346	.885097	16.4575	162.655	2.86267
6	141.920	.855174	15.8761	130.398	2.75408
7	146.131	.832180	15.4269	108.685	2.65373
8	150.083	.814770	15.0837	93.0297	2.55909
9	153.669	.801117	14.8127	81.5528	2.47273
10	156.854	.782451	14.4519	72.2534	2.39549
11	159.706	.766636	14.1460	65.0615	2.32586
12	162.185	.748536	13.8003	59.1324	2.26486
13	164.397	.730141	13.4511	54.1686	2.21005
14	166.439	.713225	13.1303	49.9707	2.15905
15	168.222	.695481	12.7959	46.3735	2.11418
16	169.836	.678694	12.4802	43.2826	2.07326
17	171.304	.662337	12.1733	40.5686	2.03577
18	172.631	.646114	11.8698	38.1606	2.00163
19	173.831	.630295	11.5745	36.0222	1.97055
20	174.922	.615007	11.2896	34.1120	1.94208

TABLE 1
SUMMARY TABULATION OF LOCAL DATA

RUN NUMBER = 28 T SUBZERO = 92.57 F
REYNOLDS NUMBER = 1979.6 T SATURATED = 210.54 F

CHAMBER	T	H	NU	GZ	GR
1	101.114	1.48401	28.1135	3500.81	4.18668
2	105.563	.925744	17.4573	800.345	3.85516
3	113.532	.878480	16.4941	414.418	3.55091
4	120.469	.815222	15.2272	251.070	3.20133
5	126.765	.806477	14.9951	179.680	2.90468
6	132.499	.789065	14.6108	139.871	2.64572
7	137.793	.777712	14.3464	114.320	2.41705
8	142.552	.743064	13.6605	96.4397	2.21560
9	146.750	.717840	13.1568	83.5154	2.04157
10	150.487	.652078	11.9195	73.5198	1.89162
11	153.793	.631879	11.5230	65.0453	1.76175
12	156.648	.572166	10.4125	59.3049	1.65060
13	159.246	.544937	9.89902	54.0702	1.55409
14	161.520	.499976	9.06753	49.6696	1.46933
15	163.531	.461781	8.36291	45.9281	1.39590
16	165.383	.446626	8.07807	42.7195	1.33059
17	166.983	.399470	7.21691	39.9351	1.27295
18	168.480	.385184	6.95169	37.4802	1.22179
19	169.750	.337507	6.08566	35.3030	1.17651
20	170.875	.308002	5.54925	33.3663	1.13768

TABLE 2
SUMMARY TABULATION OF AVERAGE DATA

CHAMBER	T	H	NU	GZ	GR
1	101.114	1.48471	28.1268	1175.37	4.18470
2	105.563	1.21009	22.8883	616.158	4.06698
3	113.532	1.04490	19.7084	316.463	3.85725
4	120.469	.966465	18.1846	211.718	3.67553
5	126.765	.925155	17.3690	159.408	3.51095
6	132.499	.896727	16.8017	127.740	3.36112
7	137.793	.875699	16.3775	106.427	3.22261
8	142.552	.855662	15.9764	91.0708	3.09769
9	146.750	.837860	15.6213	79.8175	2.98706
10	150.487	.816090	15.1957	70.7016	2.88805
11	153.793	.797258	14.8281	63.6535	2.79995
12	156.648	.776376	14.4256	57.8447	2.72338
13	159.246	.756635	14.0462	52.9815	2.65323
14	161.520	.736496	13.6617	48.8713	2.59143
15	163.531	.716520	13.2819	45.3494	2.53638
16	165.383	.698356	12.9370	42.3231	2.48536
17	166.983	.679491	12.5806	39.6673	2.44098
18	168.480	.661902	12.2487	37.3104	2.39916
19	169.750	.643645	11.9057	35.2187	2.36347
20	170.875	.625794	11.5710	33.3506	2.33168

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 1 T SUBZERO = 91.88 F
REYNOLDS NUMBER = 1741.5 T SATURATED = 210.49 F

X	GZ	NU	NUL	ERROR
.276700	1033.47	27.1184	27.3430	-.821474
.527000	541.652	21.3279	22.5192	-5.29021
1.02320	278.098	18.2589	19.5461	-6.58519
1.52570	185.997	17.1721	18.1214	-5.23841
2.02190	140.005	16.5828	17.3899	-4.64129
2.51810	112.166	16.1732	16.9016	-4.30935
3.01680	93.4360	15.8466	16.5132	-4.03665
3.51970	79.9415	15.5643	16.1528	-3.64290
4.01010	70.0563	15.3172	15.8111	-3.12368
4.52130	62.0493	15.0800	15.4132	-2.16167
5.01620	55.8588	14.8648	15.0845	-1.45669
5.51450	50.7573	14.6599	14.7225	-.424933
6.01530	46.4871	14.4637	14.3726	.633988
6.51610	42.8782	14.2761	14.0237	1.79974
7.01730	39.7865	14.0960	13.6691	3.12307
7.51430	37.1308	13.9242	13.3281	4.47238
8.01300	34.7997	13.7579	12.9925	5.89173
8.51480	32.7324	13.5968	12.6471	7.50951
9.01660	30.8981	13.4414	12.2781	9.47426
9.51800	29.2589	13.2912	11.9492	11.2313
10.0177	27.7896	13.1465	11.6325	13.0154

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 2 T SUBZERO = 110.05 F
REYNOLDS NUMBER = 1770.0 T SATURATED = 210.63 F

X	GZ	NU	NUL	ERROR
.276700	1062.64	26.9378	26.4723	1.75850
.527000	557.203	20.8360	21.2875	-2.12066
1.02320	286.299	17.5643	18.3064	-4.05367
1.52570	191.597	16.3914	16.9803	-3.46855
2.02190	144.299	15.7578	16.2867	-3.24763
2.51810	115.663	15.3248	15.7910	-2.95276
3.01680	96.3893	14.9867	15.4244	-2.83757
3.51970	82.4957	14.7008	15.1244	-2.80096
4.01010	72.3123	14.4550	14.8763	-2.83192
4.52130	64.0614	14.2223	14.5499	-2.25132
5.01620	57.6825	14.0140	14.2453	-1.62402
5.51450	52.4214	13.8172	13.9645	-1.05526
6.01530	48.0188	13.6301	13.6383	-.060124
6.51610	44.2957	13.4524	13.3404	.839456
7.01730	41.1063	13.2823	13.0125	2.07365
7.51430	38.3655	13.1207	12.7126	3.21029
8.01300	35.9595	12.9648	12.4108	4.46411
8.51480	33.8245	12.8138	12.1189	5.73377
9.01660	31.9292	12.6681	11.8180	7.19314
9.51800	30.2361	12.5276	11.5297	8.65559
10.0177	28.7185	12.3923	11.2476	10.1779

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 3 T SUBZERO = 124.95 F
REYNOLDS NUMBER = 1774.2 T SATURATED = 210.76 F

X	GZ	NU	NUL	ERROR
.276700	1076.31	26.6258	26.1296	1.89878
.527000	564.540	20.3153	20.5889	-1.32906
1.02320	290.212	16.9036	17.5810	-3.85258
1.52570	194.301	15.6669	16.2198	-3.40834
2.02190	146.391	14.9983	15.5374	-3.46921
2.51810	117.382	14.5450	15.0142	-3.12511
3.01680	97.8531	14.1958	14.6251	-2.93497
3.51970	83.7727	13.9047	14.3115	-2.84269
4.01010	73.4494	13.6578	14.0705	-2.93310
4.52130	65.0817	13.4271	13.7742	-2.51992
5.01620	58.6091	13.2223	13.5414	-2.35632
5.51450	53.2717	13.0306	13.2763	-1.85066
6.01530	48.8033	12.8497	12.9861	-1.05095
6.51610	45.0249	12.6785	12.7007	-.174942
7.01730	41.7856	12.5155	12.4311	.679149
7.51430	39.0021	12.3614	12.1729	1.54851
8.01300	36.5579	12.2130	11.9151	2.50064
8.51480	34.3892	12.0697	11.6567	3.54238
9.01660	32.4633	11.9318	11.3965	4.69691
9.51800	30.7430	11.7990	11.1403	5.91265
10.0177	29.1999	11.6711	10.9180	6.89831

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 4 T SUBZERO = 139.85 F
REYNOLDS NUMBER = 1781.9 T SATURATED = 210.72 F

X	GZ	NU	NUL	ERROR
.276700	1090.94	26.2581	26.2977	-.150644
.527000	572.360	19.7177	20.1359	-2.07674
1.02320	294.371	16.1563	16.8514	-4.12525
1.52570	197.166	14.8512	15.4318	-3.76235
2.02190	148.604	14.1444	14.7084	-3.83452
2.51810	119.195	13.6682	14.1614	-3.48241
3.01680	99.3955	13.3058	13.7394	-3.15651
3.51970	85.1163	13.0078	13.4155	-3.03917
4.01010	74.6454	12.7586	13.1664	-3.09732
4.52130	66.1539	12.5285	12.9132	-2.97909
5.01620	59.5854	12.3268	12.6953	-2.90268
5.51450	54.1665	12.1395	12.4768	-2.70292
6.01530	49.6294	11.9643	12.2159	-2.05973
6.51610	45.7917	11.7996	11.9685	-1.41104
7.01730	42.5016	11.6438	11.7192	-.643053
7.51430	39.6730	11.4969	11.5138	-.146762
8.01300	37.1895	11.3562	11.2869	.613734
8.51480	34.9858	11.2209	11.0491	1.55489
9.01660	33.0284	11.0910	10.8122	2.57849
9.51800	31.2791	10.9661	10.6019	3.43533
10.0177	29.7109	10.8463	10.3869	4.42271

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 5 T SUBZERO = 154.93 F
REYNOLDS NUMBER = 1791.1 T SATURATED = 210.69 F

X	GZ	NU	NUL	ERROR
.276700	1105.74	25.8073	26.5709	-2.87363
.527000	580.247	19.0182	19.9381	-4.61368
1.02320	298.561	15.3007	16.0637	-4.74998
1.52570	200.046	13.9247	14.5639	-4.38899
2.02190	150.824	13.1776	13.8120	-4.59355
2.51810	121.012	12.6769	13.2354	-4.22007
3.01680	100.937	12.2996	12.8018	-3.92256
3.51970	86.4584	11.9933	12.4705	-3.82618
4.01010	75.8405	11.7407	12.1824	-3.62537
4.52130	67.2276	11.5104	11.9145	-3.39132
5.01620	60.5639	11.3109	11.6903	-3.24498
5.51450	55.0651	11.1278	11.4754	-3.02916
6.01530	50.4588	10.9579	11.2586	-2.67133
6.51610	46.5621	10.7996	11.0526	-2.28929
7.01730	43.2209	10.6506	10.8423	-1.76785
7.51430	40.3482	10.5112	10.6638	-1.43138
8.01300	37.8256	10.3783	10.4614	-.793925
8.51480	35.5865	10.2510	10.2615	-.102693
9.01660	33.5975	10.1293	10.0578	.710398
9.51800	31.8200	10.0127	9.86963	1.45037
10.0177	30.2263	9.90122	9.67597	2.32794

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 6 T SUBZERO = 92.00 F
REYNOLDS NUMBER = 1552.7 T SATURATED = 210.59 F

X	GZ	NU	NUL	ERROR
.276700	921.253	25.8050	26.0254	-.847119
.527000	482.783	20.6484	21.4621	-3.79136
1.02320	247.823	17.9181	18.6900	-4.13013
1.52570	165.724	16.9329	17.3352	-2.32119
2.02190	124.724	16.3791	16.7192	-2.03402
2.51810	99.9136	15.9798	16.2628	-1.74034
3.01680	83.2269	15.6518	15.8377	-1.17415
3.51970	71.2059	15.3621	15.4523	-.583664
4.01010	62.4016	15.1052	15.0824	.151613
4.52130	55.2710	14.8565	14.6560	1.36843
5.01620	49.7601	14.6303	14.2694	2.52872
5.51450	45.2185	14.4142	13.8628	3.97745
6.01530	41.4182	14.2073	13.4500	5.63021
6.51610	38.2059	14.0096	13.0570	7.29569
7.01730	35.4538	13.8198	12.6631	9.13408
7.51430	33.0900	13.6393	12.2844	11.0294
8.01300	31.0147	13.4652	11.9222	12.9418
8.51480	29.1740	13.2966	11.5628	14.9941
9.01660	27.5394	13.1341	11.2186	17.0744
9.51800	26.0789	12.9778	10.9038	19.0207
10.0177	24.7693	12.8272	10.6173	20.8139

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 7 T SUBZERO = 110.00 F
REYNOLDS NUMBER = 1576.2 T SATURATED = 210.69 F

X	GZ	NU	NUL	ERROR
.276700	946.717	25.5466	25.3831	.644381
.527000	496.347	20.1082	20.6406	-2.57905
1.02320	254.973	17.1904	17.8878	-3.89892
1.52570	170.607	16.1267	16.5880	-2.78116
2.02190	128.469	15.5349	15.9779	-2.77252
2.51810	102.962	15.1174	15.5203	-2.59619
3.01680	85.7972	14.7825	15.1705	-2.55764
3.51970	73.4279	14.4934	14.8347	-2.30117
4.01010	64.3645	14.2410	14.5234	-1.94395
4.52130	57.0209	14.0001	14.1586	-1.11971
5.01620	51.3441	13.7829	13.8212	-.277131
5.51450	46.6640	13.5771	13.4669	.817717
6.01530	42.7458	13.3813	13.1244	1.95702
6.51610	39.4336	13.1948	12.7844	3.20989
7.01730	36.5956	13.0166	12.4340	4.68502
7.51430	34.1573	12.8473	12.1021	6.15796
8.01300	32.0168	12.6841	11.7701	7.76544
8.51480	30.1173	12.5263	11.4565	9.33753
9.01660	28.4309	12.3745	11.1384	11.0970
9.51800	26.9247	12.2283	10.8231	12.9836
10.0177	25.5745	12.0877	10.5217	14.8838

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 8 T SUBZERO = 125.07 F
REYNOLDS NUMBER = 1593.5 T SATURATED = 210.74 F

X	GZ	NU	NUL	ERROR
.276700	966.289	25.2665	25.5501	-1.10999
.527000	506.761	19.5919	20.4558	-4.22336
1.02320	260.459	16.5174	17.5671	-5.97545
1.52570	174.351	15.3861	16.2866	-5.52888
2.02190	131.341	14.7599	15.6588	-5.74066
2.51810	105.301	14.3243	15.1778	-5.62331
3.01680	87.7730	13.9812	14.8220	-5.67292
3.51970	75.1345	13.6899	14.5776	-6.08994
4.01010	65.8729	13.4396	14.3191	-6.14202
4.52130	58.3674	13.2034	13.9880	-5.60968
5.01620	52.5633	12.9926	13.6982	-5.15109
5.51450	47.7771	12.7943	13.3948	-4.48284
6.01530	43.7700	12.6067	13.0779	-3.60274
6.51610	40.3812	12.4291	12.7879	-2.80547
7.01730	37.4770	12.2599	12.4843	-1.79712
7.51430	34.9817	12.0997	12.1877	-.721924
8.01300	32.7912	11.9457	11.8780	.570126
8.51480	30.8470	11.7971	11.5877	1.80708
9.01660	29.1207	11.6540	11.2918	3.20786
9.51800	27.5783	11.5166	11.0111	4.59028
10.0177	26.1953	11.3844	10.7517	5.88468

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 9 T SUBZERO = 140.02 F
REYNOLDS NUMBER = 1603.1 T SATURATED = 210.85 F

X	GZ	NU	NUL	ERROR
.276700	980.717	24.8817	25.1795	-1.18300
.527000	514.492	18.9937	19.5347	-2.76945
1.02320	264.577	15.7767	16.4638	-4.17356
1.52570	177.194	14.5816	15.0906	-3.37272
2.02190	133.540	13.9212	14.4222	-3.47370
2.51810	107.104	13.4667	13.9157	-3.22671
3.01680	89.3065	13.1139	13.5457	-3.18726
3.51970	76.4730	12.8191	13.2348	-3.14079
4.01010	67.0623	12.5693	13.0089	-3.37894
4.52130	59.4318	12.3365	12.7588	-3.30979
5.01620	53.5305	12.1308	12.5184	-3.09584
5.51450	48.6628	11.9391	12.2640	-2.64959
6.01530	44.5856	11.7589	12.0270	-2.22883
6.51610	41.1389	11.5893	11.7439	-1.31646
7.01730	38.1838	11.4285	11.4720	-.379331
7.51430	35.6441	11.2770	11.2109	.589550
8.01300	33.4135	11.1317	10.9636	1.53298
8.51480	31.4341	10.9918	10.7117	2.61473
9.01660	29.6766	10.8577	10.4378	4.02280
9.51800	28.1062	10.7290	10.1778	5.41600
10.0177	26.6983	10.6055	9.92436	6.86338

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 10 T SUBZERO = 155.07 F
REYNOLDS NUMBER = 1585.6 T SATURATED = 210.57 F

X	GZ	NU	NUL	ERROR
.276700	978.885	24.1522	24.5972	-1.80894
.527000	513.662	18.1240	18.5586	-2.34201
1.02320	264.283	14.8026	15.0935	-1.92728
1.52570	177.076	13.5534	13.5900	-.269425
2.02190	133.499	12.8611	12.9526	-.706133
2.51810	107.107	12.3877	12.4536	-.529363
3.01680	89.3369	12.0242	12.0551	-.256511
3.51970	76.5210	11.7246	11.7206	.033888
4.01010	67.1222	11.4741	11.4605	.118423
4.52130	59.4992	11.2436	11.1899	.480334
5.01620	53.6005	11.0423	10.9940	.439747
5.51450	48.7342	10.8565	10.7700	.803515
6.01530	44.6580	10.6833	10.5406	1.35386
6.51610	41.2099	10.5215	10.3188	1.96400
7.01730	38.2533	10.3691	10.0950	2.71510
7.51430	35.7120	10.2261	9.87882	3.51569
8.01300	33.4807	10.0898	9.63100	4.76426
8.51480	31.5000	9.95914	9.39030	6.05768
9.01660	29.7404	9.83440	9.16185	7.34070
9.51800	28.1680	9.71484	8.94258	8.63580
10.0177	26.7579	9.60044	8.73518	9.90540

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 11 T SUBZERO = 91.95 F
REYNOLDS NUMBER = 1407.7 T SATURATED = 210.86 F

X	GZ	NU	NUL	ERROR
.276700	834.145	24.8136	24.6408	.701307
.527000	437.095	20.1582	20.3461	-.923310
1.02320	224.334	17.6931	17.7705	-.435485
1.52570	149.996	16.7838	16.5255	1.56317
2.02190	112.872	16.2539	15.9998	1.58780
2.51810	90.4161	15.8586	15.5183	2.19321
3.01680	75.3160	15.5257	15.0516	3.14947
3.51970	64.4411	15.2272	14.5964	4.32139
4.01010	56.4747	14.9598	14.2038	5.32290
4.52130	50.0241	14.6999	13.7403	6.98401
5.01620	45.0401	14.4627	13.2978	8.76026
5.51450	40.9318	14.2361	12.8660	10.6486
6.01530	37.4945	14.0194	12.4221	12.8580
6.51610	34.5886	13.8122	12.0078	15.0265
7.01730	32.0995	13.6141	11.5895	17.4683
7.51430	29.9614	13.4258	11.1890	19.9915
8.01300	28.0848	13.2446	10.7953	22.6886
8.51480	26.4206	13.0699	10.3980	25.6956
9.01660	24.9423	12.9016	10.0341	28.5773
9.51800	23.6217	12.7398	9.68852	31.4940
10.0177	22.4380	12.5844	9.35932	34.4594

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 12 T SUBZERO = 110.05 F
REYNOLDS NUMBER = 1393.0 T SATURATED = 210.91 F

X	GZ	NU	NUL	ERROR
.276700	835.996	24.2358	24.3315	-.393119
.527000	438.243	19.4380	19.8433	-2.04243
1.02320	225.078	16.8574	17.2325	-2.17703
1.52570	150.584	15.8932	15.9515	-.365050
2.02190	113.388	15.3362	15.2204	.760794
2.51810	90.8698	14.9283	14.7659	1.10046
3.01680	75.7200	14.5919	14.3606	1.61013
3.51970	64.8038	14.2953	13.9879	2.19757
4.01010	56.8067	14.0335	13.6292	2.96622
4.52130	50.3291	13.7815	13.1927	4.46318
5.01620	45.3210	13.5535	12.8115	5.79200
5.51450	41.1921	13.3369	12.4252	7.33807
6.01530	37.7365	13.1307	12.0308	9.14238
6.51610	34.8147	12.9345	11.6582	10.9473
7.01730	32.3112	12.7469	11.2813	12.9920
7.51430	30.1603	12.5692	10.9241	15.0600
8.01300	28.2722	12.3984	10.5672	17.3291
8.51480	26.5970	12.2335	10.2191	19.7121
9.01660	25.1094	12.0751	9.88345	22.1756
9.51800	23.7802	11.9232	9.57191	24.5647
10.0177	22.5888	11.7772	9.26718	27.0853

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 13 T SUBZERO = 125.15 F
REYNOLDS NUMBER = 1410.3 T SATURATED = 210.80 F

X	GZ	NU	NUL	ERROR
.276700	855.205	23.9030	23.8670	.150743
.527000	448.466	18.8751	19.2625	-2.01095
1.02320	230.468	16.1394	16.5928	-2.73296
1.52570	154.260	15.1103	15.4089	-1.93739
2.02190	116.197	14.5223	14.8055	-1.91323
2.51810	93.1549	14.1005	14.3530	-1.75922
3.01680	77.6466	13.7597	13.9865	-1.62156
3.51970	66.4690	13.4650	13.6503	-1.35771
4.01010	58.2777	13.2083	13.3347	-.947799
4.52130	51.6401	12.9643	12.9493	.115534
5.01620	46.5071	12.7452	12.6180	1.00828
5.51450	42.2744	12.5386	12.2782	2.12069
6.01530	38.7312	12.3430	11.9185	3.56191
6.51610	35.7356	12.1576	11.5608	5.16229
7.01730	33.1677	11.9810	11.2180	6.80171
7.51430	30.9606	11.8139	10.9083	8.30190
8.01300	29.0236	11.6534	10.5723	10.2254
8.51480	27.3045	11.4987	10.2545	12.1336
9.01660	25.7779	11.3504	9.93690	14.2247
9.51800	24.4141	11.2079	9.63258	16.3539
10.0177	23.1912	11.0711	9.34653	18.4523

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 14 T SUBZERO = 140.00 F
REYNOLDS NUMBER = 1404.2 T SATURATED = 210.77 F

X	GZ	NU	NUL	ERROR
.276700	859.924	23.3523	23.2241	.551882
.527000	451.085	18.1755	18.3208	-.793019
1.02320	231.943	15.3285	15.5373	-1.34428
1.52570	155.323	14.2470	14.3169	-.488747
2.02190	117.052	13.6315	13.6147	.123263
2.51810	93.8756	13.1957	13.1472	.369111
3.01680	78.2723	12.8491	12.7988	.393340
3.51970	67.0227	12.5541	12.4940	.480379
4.01010	58.7759	12.3008	12.2166	.688706
4.52130	52.0915	12.0624	11.8670	1.64623
5.01620	46.9211	11.8505	11.5705	2.42031
5.51450	42.6570	11.6522	11.2460	3.61188
6.01530	39.0861	11.4654	10.9240	4.95534
6.51610	36.0664	11.2892	10.6026	6.47588
7.01730	33.4776	11.1224	10.2861	8.13042
7.51430	31.2525	10.9649	9.99612	9.69185
8.01300	29.2989	10.8141	9.69555	11.5377
8.51480	27.5649	10.6691	9.40519	13.4392
9.01660	26.0247	10.5302	9.12453	15.4061
9.51800	24.6485	10.3967	8.85904	17.3578
10.0177	23.4145	10.2690	8.60810	19.2956

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 15 T SUBZERO = 154.98 F
REYNOLDS NUMBER = 1401.9 T SATURATED = 210.63 F

X	GZ	NU	NUL	ERROR
.276700	864.427	22.6876	23.0092	-1.39759
.527000	453.589	17.3512	17.3043	.270706
1.02320	233.359	14.3877	14.1581	1.62157
1.52570	156.342	13.2508	12.8821	2.86163
2.02190	117.864	12.6057	12.2340	3.03838
2.51810	94.5596	12.1542	11.7724	3.24245
3.01680	78.8689	11.8007	11.3768	3.72596
3.51970	67.5538	11.5045	11.0367	4.23849
4.01010	59.2555	11.2539	10.7816	4.38060
4.52130	52.5256	11.0211	10.5075	4.88780
5.01620	47.3192	10.8164	10.2713	5.30721
5.51450	43.0240	10.6264	10.0203	6.04884
6.01530	39.4265	10.4490	9.75390	7.12649
6.51610	36.3835	10.2827	9.49742	8.26845
7.01730	33.7741	10.1258	9.24880	9.48292
7.51430	31.5308	9.97855	9.03035	10.5001
8.01300	29.5612	9.83832	8.77991	12.0549
8.51480	27.8128	9.70369	8.53997	13.6267
9.01660	26.2595	9.57506	8.31708	15.1252
9.51800	24.8715	9.45199	8.09899	16.7058
10.0177	23.6267	9.33432	7.89702	18.2003

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 16 T SUBZERO = 92.82 F
REYNOLDS NUMBER = 1198.6 T SATURATED = 210.57 F

X	GZ	NU	NUL	ERROR
.276700	710.594	23.2931	23.1411	.656811
.527000	372.285	19.3255	19.2062	.621156
1.02320	191.019	17.2043	16.8068	2.36473
1.52570	127.681	16.3788	15.8029	3.64438
2.02190	96.0704	15.8653	15.2295	4.17502
2.51810	76.9551	15.4630	14.6840	5.30493
3.01680	64.1047	15.1139	14.1569	6.75967
3.51970	54.8500	14.7959	13.6760	8.18906
4.01010	48.0727	14.5093	13.2335	9.64109
4.52130	42.5863	14.2301	12.7128	11.9357
5.01620	38.3472	13.9757	12.2265	14.3060
5.51450	34.8544	13.7332	11.7232	17.1452
6.01530	31.9310	13.5020	11.2455	20.0662
6.51610	29.4599	13.2823	10.7891	23.1085
7.01730	27.3426	13.0728	10.3511	26.2938
7.51430	25.5236	12.8749	9.93945	29.5335
8.01300	23.9266	12.6849	9.54994	32.8269
8.51480	22.5099	12.5019	9.17127	36.3169
9.01660	21.2516	12.3267	8.81929	39.7706
9.51800	20.1276	12.1585	8.48649	43.2689
10.0177	19.1202	11.9978	8.16216	46.9933

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 17 T SUBZERO = 109.95 F
REYNOLDS NUMBER = 1195.0 T SATURATED = 210.26 F

X	GZ	NU	NUL	ERROR
.276700	717.049	22.7197	22.6902	.129981
.527000	375.828	18.5897	18.7015	-.597368
1.02320	192.965	16.3431	16.4561	-.686702
1.52570	129.065	15.4648	15.3837	.527113
2.02190	97.1653	14.9293	14.7670	1.09910
2.51810	77.8620	14.5203	14.2862	1.63873
3.01680	64.8800	14.1733	13.8193	2.56172
3.51970	55.5284	13.8627	13.3734	3.65893
4.01010	48.6779	13.5861	12.9600	4.83061
4.52130	43.1290	13.3191	12.4907	6.63228
5.01620	38.8402	13.0773	12.0579	8.45353
5.51450	35.3048	12.8480	11.6159	10.6065
6.01530	32.3457	12.6298	11.1794	12.9744
6.51610	29.8443	12.4231	10.7541	15.5195
7.01730	27.7005	12.2263	10.3420	18.2201
7.51430	25.8588	12.0404	9.95114	20.9953
8.01300	24.2417	11.8622	9.57554	23.8802
8.51480	22.8068	11.6910	9.21799	26.8289
9.01660	21.5325	11.5270	8.87304	29.9103
9.51800	20.3940	11.3698	8.54643	33.0359
10.0177	19.3733	11.2194	8.24044	36.1509

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 18 T SUBZERO = 124.98 F
REYNOLDS NUMBER = 1194.8 T SATURATED = 210.38 F

X	GZ	NU	NUL	ERROR
.276700	724.282	22.2396	21.9865	1.15107
.527000	379.766	17.9647	17.8627	.571093
1.02320	195.124	15.6105	15.4814	.834038
1.52570	130.584	14.6869	14.3993	1.99721
2.02190	98.3534	14.1319	13.8310	2.17499
2.51810	78.8415	13.7165	13.4340	2.10292
3.01680	65.7151	13.3707	13.0293	2.62033
3.51970	56.2576	13.0657	12.6108	3.60755
4.01010	49.3272	12.7972	12.2298	4.63935
4.52130	43.7111	12.5401	11.8102	6.17968
5.01620	39.3697	12.3089	11.4071	7.90510
5.51450	35.7894	12.0905	11.0152	9.76190
6.01530	32.7926	11.8838	10.6049	12.0589
6.51610	30.2583	11.6882	10.2266	14.2911
7.01730	28.0856	11.5021	9.87052	16.5299
7.51430	26.2189	11.3266	9.52413	18.9258
8.01300	24.5801	11.1587	9.17774	21.5847
8.51480	23.1255	10.9972	8.85431	24.2021
9.01660	21.8339	10.8427	8.53284	27.0706
9.51800	20.6795	10.6950	8.24571	29.7044
10.0177	19.6445	10.5535	7.96852	32.4405

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 19 T SUBZERO = 139.87 F
REYNOLDS NUMBER = 1196.2 T SATURATED = 210.47 F

X	GZ	NU	NUL	ERROR
.276700	732.075	21.7051	21.8914	-.850867
.527000	383.981	17.2766	17.3717	-.547227
1.02320	197.400	14.8098	14.8889	-.530750
1.52570	132.173	13.8381	13.7303	.784831
2.02190	99.5886	13.2611	13.2107	.381894
2.51810	79.8647	12.8377	12.7100	1.00491
3.01680	66.5881	12.4917	12.3138	1.44524
3.51970	57.0160	12.1914	11.9967	1.62321
4.01010	50.0014	11.9303	11.6597	2.32019
4.52130	44.3150	11.6827	11.2930	3.45046
5.01620	39.9184	11.4617	10.9321	4.84464
5.51450	36.2920	11.2543	10.5713	6.46074
6.01530	33.2551	11.0590	10.2222	8.18550
6.51610	30.6865	10.8747	9.89829	9.86439
7.01730	28.4851	10.7002	9.55556	11.9787
7.51430	26.5928	10.5358	9.24858	13.9183
8.01300	24.9317	10.3785	8.92247	16.3196
8.51480	23.4569	10.2277	8.62644	18.5627
9.01660	22.1469	10.0835	8.34584	20.8208
9.51800	20.9764	9.94551	8.07703	23.1332
10.0177	19.9269	9.81360	7.81526	25.5697

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 20 T SUBZERO = 155.05 F
REYNOLDS NUMBER = 1201.2 T SATURATED = 210.57 F

X	GZ	NU	NUL	ERROR
.276700	740.433	21.0727	21.2336	-.757858
.527000	388.508	16.4783	16.0017	2.97798
1.02320	199.850	13.8921	13.3513	4.05050
1.52570	133.888	12.8687	12.0155	7.10030
2.02190	100.928	12.2676	11.4928	6.74139
2.51810	80.9692	11.8341	11.0286	7.30431
3.01680	67.5319	11.4867	10.6362	7.99634
3.51970	57.8418	11.1903	10.3119	8.51874
4.01010	50.7366	10.9364	10.0372	8.95945
4.52130	44.9756	10.6984	9.70727	10.2111
5.01620	40.5188	10.4880	9.42972	11.2236
5.51450	36.8425	10.2921	9.12829	12.7503
6.01530	33.7631	10.1086	8.83173	14.4582
6.51610	31.1583	9.93649	8.55010	16.2148
7.01730	28.9245	9.77428	8.28628	17.9573
7.51430	27.0046	9.62189	8.03367	19.7695
8.01300	25.3183	9.47667	7.78572	21.7185
8.51480	23.8215	9.33755	7.54515	23.7557
9.01660	22.4917	9.20481	7.31875	25.7701
9.51800	21.3033	9.07798	7.10580	27.7544
10.0177	20.2375	8.95657	6.90848	29.6460

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 21 T SUBZERO = 92.00 F
REYNOLDS NUMBER = 999.5 T SATURATED = 210.99 F

X	GZ	NU	NUL	ERROR
.276700	590.656	21.9671	22.2690	-1.35577
.527000	309.329	18.6970	18.6788	.097880
1.02320	158.620	16.9164	16.4677	2.72507
1.52570	105.983	16.1634	15.4688	4.49041
2.02190	79.7239	15.6533	14.8814	5.18663
2.51810	63.8509	15.2317	14.3225	6.34745
3.01680	53.1835	14.8555	13.7906	7.72181
3.51970	45.5059	14.5090	13.2521	9.48445
4.01010	39.8859	14.1954	12.7352	11.4653
4.52130	35.3363	13.8898	12.1649	14.1799
5.01620	31.8212	13.6124	11.6422	16.9223
5.51450	28.9246	13.3492	11.1224	20.0213
6.01530	26.5012	13.1000	10.6002	23.5823
6.51610	24.4523	12.8639	10.1243	27.0588
7.01730	22.6965	12.6400	9.67078	30.7032
7.51430	21.1883	12.4288	9.24172	34.4865
8.01300	19.8638	12.2274	8.84589	38.2279
8.51480	18.6886	12.0344	8.47057	42.0735
9.01660	17.6445	11.8502	8.13023	45.7550
9.51800	16.7117	11.6747	7.81329	49.4218
10.0177	15.8750	11.5071	7.52618	52.8950

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 22 T SUBZERO = 109.88 F
REYNOLDS NUMBER = 1042.7 T SATURATED = 210.75 F

X	GZ	NU	NUL	ERROR
.276700	625.637	21.6820	21.8847	-.926253
.527000	327.842	18.0902	18.2434	-.839846
1.02320	168.272	16.1123	16.0966	.097709
1.52570	112.521	15.2998	15.0968	1.34453
2.02190	84.6911	14.7766	14.5707	1.41281
2.51810	67.8603	14.3614	14.0515	2.20570
3.01680	56.5454	14.0011	13.5175	3.57777
3.51970	48.3955	13.6744	13.0235	4.99791
4.01010	42.4269	13.3820	12.5508	6.62262
4.52130	37.5930	13.0989	12.0235	8.94407
5.01620	33.8568	12.8427	11.5442	11.2471
5.51450	30.7774	12.5998	11.0554	13.9698
6.01530	28.1993	12.3696	10.5962	16.7361
6.51610	26.0202	12.1518	10.1458	19.7722
7.01730	24.1529	11.9455	9.70514	23.0848
7.51430	22.5481	11.7508	9.30630	26.2679
8.01300	21.1392	11.5649	8.91836	29.6752
8.51480	19.8889	11.3864	8.55210	33.1424
9.01660	18.7782	11.2157	8.21386	36.5464
9.51800	17.7857	11.0528	7.90069	39.8966
10.0177	16.8960	10.8973	7.60303	43.3285

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 23 T SUBZERO = 125.00 F
REYNOLDS NUMBER = 995.2 T SATURATED = 211.01 F

X	GZ	NU	NUL	ERROR
.276700	601.768	20.8088	20.2907	2.55321
.527000	315.479	17.2598	16.5482	4.30050
1.02320	162.047	15.2676	14.4493	5.66367
1.52570	108.420	14.4363	13.5626	6.44250
2.02190	81.6427	13.9031	13.1095	6.05363
2.51810	65.4435	13.4847	12.6272	6.79125
3.01680	54.5486	13.1256	12.1343	8.16914
3.51970	46.6998	12.8033	11.6532	9.86984
4.01010	40.9493	12.5171	11.2063	11.6965
4.52130	36.2894	12.2417	10.7362	14.0226
5.01620	32.6874	11.9936	10.2955	16.4938
5.51450	29.7176	11.7597	9.85165	19.3686
6.01530	27.2299	11.5382	9.46030	21.9652
6.51610	25.1270	11.3294	9.06985	24.9138
7.01730	23.3244	11.1317	8.69726	27.9915
7.51430	21.7753	10.9459	8.35446	31.0196
8.01300	20.4148	10.7685	8.02909	34.1192
8.51480	19.2077	10.5985	7.71009	37.4636
9.01660	18.1355	10.4364	7.40373	40.9623
9.51800	17.1773	10.2816	7.12830	44.2377
10.0177	16.3182	10.1337	6.86724	47.5661

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 24 T SUBZERO = 155.00 F
REYNOLDS NUMBER = 2006.4 T SATURATED = 210.72 F

X	GZ	NU	NUL	ERROR
.276700	1239.69	27.5307	27.4562	.271570
.527000	650.566	19.9327	20.5425	-2.96852
1.02320	334.772	15.7902	16.4373	-3.93733
1.52570	224.327	14.2748	14.8326	-3.76027
2.02190	169.143	13.4652	14.0263	-4.00066
2.51810	135.719	12.9319	13.3914	-3.43154
3.01680	113.211	12.5367	12.9064	-2.86485
3.51970	96.9779	12.2207	12.5158	-2.35730
4.01010	85.0713	11.9633	12.2220	-2.11628
4.52130	75.4145	11.7313	11.8925	-1.35551
5.01620	67.9420	11.5320	11.6409	-.934952
5.51450	61.7763	11.3503	11.3786	-.248938
6.01530	56.6108	11.1827	11.1300	.472853
6.51610	52.2406	11.0271	10.9024	1.14341
7.01730	48.4924	10.8813	10.6978	1.71513
7.51430	45.2707	10.7449	10.4930	2.40099
8.01300	42.4410	10.6153	10.2828	3.23379
8.51480	39.9289	10.4912	10.0832	4.04617
9.01660	37.6977	10.3727	9.87125	5.08079
9.51800	35.7035	10.2593	9.68357	5.94593
10.0177	33.9151	10.1507	9.50315	6.81493

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 25 T SUBZERO = 139.87 F
REYNOLDS NUMBER = 2010.3 T SATURATED = 210.41 F

X	GZ	NU	NUL	ERROR
.276700	1231.47	27.9885	27.4125	2.10132
.527000	646.129	20.6095	20.9660	-1.70034
1.02320	332.368	16.6010	17.2013	-3.48986
1.52570	222.640	15.1487	15.7257	-3.66926
2.02190	167.825	14.3766	14.8938	-3.47251
2.51810	134.626	13.8676	14.2816	-2.89891
3.01680	112.273	13.4883	13.7912	-2.19620
3.51970	96.1533	13.1823	13.4031	-1.64731
4.01010	84.3316	12.9306	13.1024	-1.31122
4.52130	74.7451	12.7012	12.7716	-.551181
5.01620	67.3273	12.5021	12.5279	-.205963
5.51450	61.2077	12.3188	12.2758	.350721
6.01530	56.0815	12.1482	12.0363	.930009
6.51610	51.7455	11.9885	11.8024	1.57690
7.01730	48.0284	11.8379	11.5551	2.44773
7.51430	44.8339	11.6963	11.3118	3.39848
8.01300	42.0287	11.5609	11.0570	4.55737
8.51480	39.5386	11.4306	10.8163	5.67911
9.01660	37.3276	11.3057	10.5553	7.10910
9.51800	35.3514	11.1858	10.3265	8.32123
10.0177	33.5796	11.0706	10.0968	9.64408

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 26 T SUBZERO = 125.05 F
REYNOLDS NUMBER = 1995.2 T SATURATED = 210.22 F

X	GZ	NU	NUL	ERROR
.276700	1211.06	28.2202	27.1466	3.95474
.527000	635.279	21.1123	21.2362	-.583651
1.02320	326.640	17.2699	17.9391	-3.73029
1.52570	218.727	15.8910	16.4643	-3.48193
2.02190	164.822	15.1604	15.6496	-3.12560
2.51810	132.180	14.6771	15.0254	-2.31822
3.01680	110.206	14.3139	14.5270	-1.46728
3.51970	94.3615	14.0177	14.1243	-.754797
4.01010	82.7417	13.7708	13.8397	-.497834
4.52130	73.3211	13.5432	13.5178	.187662
5.01620	66.0345	13.3435	13.2395	.785227
5.51450	60.0248	13.1578	12.9424	1.66435
6.01530	54.9915	12.9835	12.6599	2.55613
6.51610	50.7362	12.8192	12.3546	3.76088
7.01730	47.0877	12.6633	12.0685	4.92873
7.51430	43.9525	12.5159	11.7909	6.14810
8.01300	41.1996	12.3742	11.5101	7.50780
8.51480	38.7561	12.2376	11.2468	8.80940
9.01660	36.5866	12.1060	10.9720	10.3353
9.51800	34.6480	11.9792	10.7168	11.7798
10.0177	32.9107	11.8572	10.4479	13.4883

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 27 T SUBZERO = 110.00 F
REYNOLDS NUMBER = 1990.8 T SATURATED = 210.43 F

X	GZ	NU	NUL	ERROR
.276700	1196.96	28.5310	27.4554	3.91786
.527000	627.714	21.6590	21.8822	-1.01989
1.02320	322.598	17.9699	18.7031	-3.92019
1.52570	215.933	16.6621	17.2318	-3.30636
2.02190	162.655	15.9724	16.4575	-2.94766
2.51810	130.398	15.5144	15.8761	-2.27816
3.01680	108.685	15.1669	15.4269	-1.68518
3.51970	93.0297	14.8797	15.0837	-1.35240
4.01010	81.5528	14.6372	14.8127	-1.18500
4.52130	72.2534	14.4109	14.4519	-.283657
5.01620	65.0615	14.2098	14.1460	.451009
5.51450	59.1324	14.0212	13.8003	1.60049
6.01530	54.1686	13.8427	13.4511	2.91158
6.51610	49.9707	13.6733	13.1303	4.13501
7.01730	46.3735	13.5115	12.7959	5.59215
7.51430	43.2826	13.3579	12.4802	7.03296
8.01300	40.5686	13.2097	12.1733	8.51304
8.51480	38.1606	13.0660	11.8698	10.0772
9.01660	36.0222	12.9273	11.5745	11.6878
9.51800	34.1120	12.7934	11.2896	13.3205
10.0177	32.4003	12.6641	10.9931	15.2008

TABLE 3

CORRELATION OF AVERAGE NUSSELT NUMBER

RUN NUMBER = 28 T SUBZERO = 92.57 F
REYNOLDS NUMBER = 1979.6 T SATURATED = 210.54 F

X	GZ	NU	NUL	ERROR
.276700	1175.37	28.7721	28.1268	2.29455
.527000	616.158	22.1849	22.8883	-3.07304
1.02320	316.463	18.6825	19.7084	-5.20578
1.52570	211.718	17.4587	18.1846	-3.99176
2.02190	159.408	16.8158	17.3690	-3.18530
2.51810	127.740	16.3856	16.8017	-2.47651
3.01680	106.427	16.0542	16.3775	-1.97407
3.51970	91.0708	15.7756	15.9764	-1.25639
4.01010	79.8175	15.5364	15.6213	-.543418
4.52130	70.7016	15.3097	15.1957	.749873
5.01620	63.6535	15.1058	14.8281	1.87260
5.51450	57.8447	14.9126	14.4256	3.37583
6.01530	52.9815	14.7280	14.0462	4.85388
6.51610	48.8713	14.5518	13.6617	6.51599
7.01730	45.3494	14.3826	13.2819	8.28698
7.51430	42.3231	14.2210	12.9370	9.92517
8.01300	39.6673	14.0647	12.5806	11.7962
8.51480	37.3104	13.9127	12.2487	13.5850
9.01660	35.2187	13.7655	11.9057	15.6210
9.51800	33.3506	13.6232	11.5710	17.7356
10.0177	31.6763	13.4858	11.2446	19.9313

Table 4. Chamber Dimensions

Chamber No.	A_i (ft.^{2})	x_i (ft.)	A_{x_i} (ft.^{2})	x_{x_i} (ft.)
1	0.2794	0.2767	0.2794	0.0929
2	0.5321	0.5270	0.2474	0.4045
3	1.0331	1.0232	0.4956	0.7778
4	1.5405	1.5257	0.5019	1.2772
5	2.0415	2.0219	0.4956	1.7765
6	2.5425	2.5181	0.4956	2.2727
7	3.0461	3.0168	0.4981	2.7702
8	3.5538	3.5197	0.5023	3.2726
9	4.0490	4.0101	0.4897	3.7676
10	4.5652	4.5213	0.5107	4.2684
11	5.0649	5.0162	0.4943	4.8131
12	5.5680	5.5145	0.4977	5.2681
13	6.0736	6.0153	0.5002	5.7676
14	6.5793	6.5161	0.5002	6.2684
15	7.0854	7.0173	0.5006	6.7694
16	7.5872	7.5143	0.4964	7.2685
17	8.0907	8.0130	0.4981	7.7664
18	8.5974	8.5148	0.5012	8.2666
19	9.1041	9.0166	0.5012	8.7684
20	9.6103	9.5180	0.5008	9.2700
21	10.1149	10.0177	0.4991	9.7705

APPENDIX B

CALCULATION PROCEDURE

PART I

Development of Equation 3:

The heat transfer, q, to a fluid flowing in a tube of diameter, D, for a length of tube, x, measured from the entrance, is

$$q = h_{lm} A \Delta T_{lm} = \mathring{m} c_p (T - T_o)$$

where

$$h_{lm} = \frac{k}{D} Nu_{lm}$$

$$\Delta T_{lm} = \frac{T - T_o}{\ln \frac{T_w - T_o}{T_w - T}}$$

$$A = \pi D x$$

Substitution for the three terms above results in

$$\ln \frac{T_w - T_o}{T_w - T} = \frac{\pi Nu_{lm}}{Gz}$$

where

$$Gz = \frac{\mathring{m} \cdot c_p}{k \cdot x}$$

Solving for T

$$T = T_w - (T_w - T_o) e^{-\frac{\pi Nu_{lm}}{Gz}}$$

$$\frac{T - T_o}{T_w - T_o} = 1 - e^{-\frac{\pi Nu_{lm}}{Gz}}$$

and

$$\Delta T_{lm} = \frac{Gz}{\pi\, Nu_{lm}} (T_w - T_o)\left(1 - e^{-\frac{\pi\, Nu_{lm}}{Gz}}\right) \qquad (3)$$

CALCULATION PROCEDURE

PART II

All the coefficients in Tables 1, 2, and 3 were calculated by the Burroughs 220 computer of the Georgia Institute of Technology. Values for the average Nusselt Number obtained from equation 2 were compared with those in Table 2, and the results were printed on Table 3. The equations for the properties of air were determined by the method of least squares fit (11)

The outline of the program used to calculate the values in Tables 1, 2, and 3 follows.

(a) Program for Tables 1 and 2

Input data:

T_g = temperature of the air at the gas meter (°F)

T_s = saturation temperature of the steam at P_s, used as the tube wall temperature (°F)

T_o = temperature of the inlet air (°F)

τ = run time (seconds)

V_a = volume of air corresponding to (cubic feet)

h_{fg} = latent heat of vaporization of the steam at P_s* (BTU/lb_m)

γ = specific humidity of the air (lb_m water/lb_m dry air)

P_a = pressure of the air entering the gas meter (inches of mercury absolute)

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*From reference (10).

P_s = pressure of the steam in the chest (inches of mercury absolute)

Run number

V_i = volume of condensate in each burette** (cu. cm.)

A_i = area of the tube from the entrance to section i (sq. ft.)

x_i = length of tube from entrance to section i (ft.)

A_{xi} = area of tube from (i - 1) to i (sq. ft.)

x_{xi} = length of tube from (i - 1) to i (ft.)

Output data:

Run Number

T_o = temperature of the inlet air (°F)

Re = Reynolds number based on the properties of air at the gas meter temperature T_g.

T_s = saturation temperature of the steam (°F)

Chamber Number

T_i = temperature of the air in each chamber (°F)

h_{xi} = local heat transfer coefficient at i (BTU/sq. ft. hr. °F)

Nu_{xi} = local Nusselt number at i

Gz_{xi} = local Graetz number at i

h_i = average heat transfer coefficient based on the logarithmic temperature difference from entrance to section i.

Nu_i = average Nusselt number at i

**i = 2,3, ..., 22.

Gz_i = average Graetz number at i

Gr_i = average Grashof number

Computations:

Specific volume of air,

$$v = \frac{(53.35 + 85.58\gamma)(T_g + 460)}{(1 + \gamma)(70.73\ P_a)}$$

$$v = \frac{\text{cubic feet of mixture}}{\text{lb}_m \text{ of mixture}}$$

Specific heat of air at constant pressure,

$$c_p = \frac{0.24 + 0.446\gamma}{1 + \gamma}$$

$$c_p = \frac{\text{BTU}}{\text{lb}_m \text{ mixture } ^\circ\text{F}}$$

Mass rate of flow,

$$\mathring{m} = \frac{3{,}600\ V_a}{\tau\ v}$$

$$\mathring{m} = \frac{\text{lb}_m \text{ of mixture}}{\text{hour}}$$

Reynolds number,

$$Re = \frac{\bar{V}\ D}{\mu} = \frac{4\ \mathring{m}}{\pi\ D\ \mu}$$

where D = diameter of tube = 0.3214 ft.

μ = dynamic viscosity of air (lb/hr.ft)

$$\mu = 3.9383352.10^{-2} + [6.8045312.10^{-5} - (6.1050061.10^{-9})T_o]T_o$$

Heat transfer at i,

$$q_i = m_i h_{fg}$$

where m_i = mass of condensate (lb_m/hr)

$$m_i = \frac{7.93\ V_i}{\tau}$$

$$q_i = \frac{7.93\ V_i\ h_{fg}}{\tau}$$

$$q_i = \frac{BTU}{hr}$$

Correction for the first 0.38 inches of tube where no condensate was collected. Assuming Polhausen's solution for a flat plate modified for a tube holds at the entrance of the tube:

$$*** \quad Nu = 0.664(Pr)^{1/3}\ (Re)^{1/2}$$

where the Nusselt and Reynolds number are based on the length, L = 0.38 in. = 0.03165 ft.

Assume,

$$Pr = 0.70$$

The heat transfer for the first 0.38 inches

$$q_{oa} = h\ A\ (T_s - T_o)$$

$$= 0.1869\ k_o(T_s - T_o)(Re)^{1/2}$$

***Reference 9.

where k_o is based on the inlet temperature T_o

$$k_o = 1.3133711.10^{-2} + [(2.5870573.10^{-5}) - (6.1050061.10^{-9})T_o]T_o$$

The heat transfer from the entrance to the first chamber ($i = 2$),

$$q_2 = q_2 + q_{oa}$$

Total heat transfer from the entrance to section i,

$$\Sigma q_i = \Sigma q_{i-1} + q_i$$

The air temperature increase from the entrance to i,

$$\Delta T_i = \frac{\Sigma q_i}{\dot{m} c_p}$$

Temperature at section i,

$$T_i = T_o + \Delta T_i$$

Temperature difference between the wall and air at i,

$$\Delta T_{wi} = T_w - T_i$$

The logarithmic mean temperature difference from the entrance to section i,

$$(\Delta T_i)_{lm} = \frac{-\Delta T_i}{\ln \frac{\Delta T_{wi}}{T_w - T_o}}$$

The average heat transfer coefficient from entrance to section i,

$$h_i = \frac{\Sigma q_i}{A_i(\Delta T_i)_{lm}}$$

The average Nusselt number at i,

$$Nu_{L(i)} = \frac{h_i D}{k_f} = \frac{0.3214\ h_i}{k_f}$$

The average Graetz number,

$$Gz_i = \frac{\dot{m}\ c_p}{k_f\ x_i}$$

where k_f is the thermal conductivity of air based on the average film temperature,

$$k_f = 1.3133711.10^{-2} + [(2.5870573.10^{-5}) - (6.1050061.10^{-9})\ T_f]\ T_f$$

The average film temperature at i,

$$T_f = \frac{\frac{T_o + T_w}{2} + \frac{T_w + T_i}{2}}{2}$$

$$T_f = \frac{2T_w + T_o + T_i}{4}$$

The average Grashof number,

$$Gr_i = \frac{\rho^2 \beta\ g\ D^3}{\mu^2} (\Delta T_i)_{lm}$$

Setting

$$\frac{\rho^2 \beta\ g}{\mu^2} = Z_f$$

$$Z_f = 4.3348727 + \Big[-(4.2120649.10^{-2}) + \{(2.2256586.10^{-4}) + [-6.6493277.10^{-7} + (8.4383861.10^{-10})T_f]T_f\}T_f\Big]\ T_f.10^6$$

ρ is based on the standard atmospheric pressure; therefore a pressure correction must be included (M_f)

$$M_f = D^3 \text{ (pressure correction)}$$

$$M_f = 0.0332 \left(\frac{P_a}{29.92}\right)^2$$

The average Grashof number is then written as,

$$Gr_i = Z_f \, M_f (\Delta T_i)_{lm}$$

As a point of departure we set,

$$T_1 = T_o$$

The arithmetic mean temperature difference,

$$(\Delta T_i)_{am} = \frac{(T_w - T_{i-1}) + (T_w - T_i)}{2}$$

The local heat transfer coefficient based on the arithmetic mean temperature difference,

$$h_{xi} = \frac{q_i}{A_{xi} \, (\Delta T_i)_{am}}$$

The local Nusselt number,

$$Nu_{xi} = \frac{h_{xi} \, D}{k_{fx}} = \frac{0.3214 \, h_{xi}}{k_{fx}}$$

The local Graetz number,

$$Gz_{xi} = \frac{\dot{m}\, c_p}{x_{xi}\, k_{fx}}$$

where the properties of air are taken at the local film temperature T_{fx},

$$T_{fx} = \frac{\frac{T_w + T_{i-1}}{2} + \frac{T_w + T_i}{2}}{2}$$

$$= \frac{2\,T_w + T_i + T_{i-1}}{4}$$

The heat conductivity based on the local film temperature is then,

$$k_{fx} = 1.3133711.10^{-2} + [(2.5870573.10^{-5}) - (6.1050061)\, T_{fx}\,]\, T_{fx}$$

The local Grashof number,

$$Gr_{xi} = \frac{\beta\, \rho^2 g\, D^3}{\mu^2} (\Delta T_i)_{am}$$

setting

$$\frac{\beta\, \rho^2 g}{\mu^2} = Z_{fx}$$

$$Z_{fx} = 4.3348727 + \Big[- (4.2120649.10^{-2}) + \Big\{ (2.2256586.10^{-4}) + [- (6.6493277.10^{-7}) + (8.4383861.10^{-10}) T_{fx}] T_{fx} \Big\} T_{fx} \Big] T_{fx}$$

The local Grashof number is then written as,

$$Gr_{xi} = Z_{fx}\, M_f\, (\Delta T_i)_{am}$$

Sample calculations for run number 6.

Input data:

$T_g = 97.08°F$

$T_s = 210.59°F = T_w$

$T_o = 92°F$

$\tau = 3{,}600$ sec.

$V_a = 259.25$ cu. ft.

$h_{fg} = 971.30 \frac{BTU}{lb_m}$

$Y = 0.0147 \frac{lb_m \text{ water}}{lb_m \text{ dry air}}$

$P_a = 29.105$ in. Hg.

$P_s = 29.093$ in. Hg.

$V_2 = 14.05$, $V_3 = 10.8875$, $V_4 = 19.325$, $V_5 = 16.575$,

$V_6 = 15.25$, $V_7 = 13.575$, $V_8 = 11.9125$, $V_9 = 10.6125$,

$V_{10} = 9.05$, $V_{11} = 7.975$, $V_{12} = 6.8375$, $V_{13} = 5.875$,

$V_{14} = 5.075$, $V_{15} = 4.50$, $V_{16} = 3.875$, $V_{17} = 3.375$,

$V_{18} = 3.025$, $V_{19} = 2.6875$, $V_{20} = 2.35$, $V_{21} = 2.2125$,

$V_{22} = 2.10$.

Specific volume of air,

$$v = \frac{(53.35 + 85.58 \times 0.0147)(97.08 + 460)}{(1 + 0.0147)(70.73 \times 29.105)} = 14.56$$

Specific heat,

$$c_p = \frac{0.24 + 0.446 \times 0.0147}{1 + 0.0147} = 0.243$$

Mass rate of flow,

$$\dot{m} = \frac{3,600 \times 259.25}{3,600 \times 14.56} = 17.8$$

Reynolds number

$$Re = \frac{4 \times 17.8}{\pi \; 0.3214 \; \mu} = 1,552.7$$

where

$$\mu = 45.59 \times 10^{-3}$$

Correction for the first 0.38 inches of the tube where no condensate was collected,

$$q_{oa} = 0.1869 \; k_o \; (Re)^{1/2} \; (T_w - T_o)$$

$$= 13.5$$

where

$$k_o = 1.546 \times 10^{-2}$$

$$(Re)^{1/2} = 89.45$$

Heat transferred from the entrance to the first chamber $(i = 2)$

$$q_2 = q_2 + q_{oa} = \frac{7.93 \times 14.05 \times 971.30}{3,600} + 13.5 = 43.61$$

Temperature increase,

$$\Delta T_2 = \frac{q_2}{\dot{m} c_p} = \frac{43.61}{17.8 \times 0.243} = 10.071$$

Temperature of the air in the first chamber,

$$T_2 = 92.0 + 10.071 = 102.071$$

Temperature difference in the first chamber,

$$\Delta T_{wi} = 210.59 - 102.071 = 108.519$$

The logarithmic temperature difference,

$$(\Delta t_2)_{lm} = \frac{-10.071}{\ln \frac{108.519}{118.59}} = 113.7$$

The average heat transfer coefficient up to the first chamber,

$$h_2 = \frac{43.61}{0.3214\ \pi \frac{3.38}{12} \times 113.7} = 1.374$$

Average film temperature,

$$T_f = \frac{2 \times 210.59 + 92.0 + 102.071}{4} = 153.81$$

Average Nusselt number,

$$Nu_{L2} = \frac{1.374 \times 0.3214}{0.01697} = 26.025$$

Average Graetz number,

$$Gz_2 = \frac{17.8 \times 0.243}{0.01697 \times \frac{3.38}{12}} = 921.25$$

where

$$k_f = 0.01697$$

Average Grashof number,

$$Gr_2 = 1.18 \times 0.0314 \times 113.7 \times 10^6 = 4.183 \times 10^6$$

where

$$Z_f = 1.18 \times 10^6$$

$$M_f = 0.0314$$

The arithmetic mean temperature difference,

$$(\Delta T_i)_{am} = \frac{(210.59 - 92) + (210.59 - 102.071)}{2} = 113.56$$

Local heat transfer coefficient,

$$h_{x2} = \frac{43.61}{0.3214 \times \frac{3.38}{12} \times 113.56} = 1.373$$

Local Nusselt number,

$$Nu_{x2} = \frac{0.3214 \times 1.373}{0.01697} = 26.008$$

Local Graetz number,

$$Gz_{x2} = \frac{17.8 \times 0.243}{0.01697 \times 0.0929} = 2,743.92$$

where the local film temperature is

$$T_{fx} = \frac{2 \times 210.59 + 102.071 + 92.0}{4} = 153.81$$

and

$$k_{fx} = 0.01697$$

Local Grashof number,

$$Gr_{x_2} = 1.18 \times 0.0314 \times 113.56 \times 10^6 = 4.186 \times 10^6$$

where

$$Z_{fx} = 1.18 \times 10^6$$

$$M_{fx} = 0.0314$$

b) Program for Table 3:

The program for Table 3 is the same as that for Tables 1 and 2 up to the point where the average Grashof number is calculated; from then on the program is the following:

Average Nusselt number (using equation 5),

$$Nu = 1.74\, Gz_i^{0.4}$$

Define a test Nusselt number Nu_t,

$$Nu_t = Nu$$

The logarithmic mean temperature difference from the entrance to section i,

$$(\Delta T)_{lm} = (T_s - T_o) \frac{Gz_i}{\pi\, Nu} \left(1 - e^{-\frac{\pi\, Nu}{Gz_i}}\right)$$

Average film temperature difference,

$$T_f = \frac{3\, T_s + T_o - (T_s - T_o)\, e^{-\frac{\pi\, Nu}{Gz_i}}}{4}$$

Average Grashof number,

$$Gr_f = Z_f \, M_f \, \Delta T_{lm}$$

where

$$Z_f = \frac{\beta \, g \, \rho^2}{\mu^2}$$

and

$$M_f = (0.0332)\left(\frac{P_a}{29.92}\right)^2$$

$$Z_f = 4.3348727 + \Big[- (4.2120649.10^{-2} + \{(2.2256586.10^{-4})$$

$$+ [- 6.6493277.10^{-7} + (8.4383861.10^{-10})T_f]T_f\}T_f\Big] \, T_f.10^6$$

Equation 2,

$$Nu = (0.0129.Gz_i + 11.40)\left(\frac{Gr_f}{1.5 \times 10^6}\right)^{0.722 \, - \, 0.0911 \, \ln Gz_i}$$

At this point the computer was instructed to compare the value for the average Nusselt number obtained from equation 2 with the test Nusselt number defined previously. If the discrepancy was more than 0.001, the value just obtained from equation 2 was set equal to the test Nusselt number, and the procedure was repeated until the discrepancy was less than 0.001.

Once the discrepancy between the test Nusselt number and that of equation 2 was within 0.001, the error in the value of the Nusselt number as given by equation 2 was obtained by comparing it with the average Nusselt number from Table 2,

$$\text{Error} = \frac{Nu - Nu_{Li}}{Nu_{Li}} \times 100.0$$

Sample Calculation for Run No. 6:

From Table 2, the average Graetz number,

$$Gz_i = 921$$

The average Nusselt number,

$$Nu = 1.74(921)^{0.4} = 26.6$$

$$Nu_t = Nu = 26.6$$

The logarithmic temperature difference,

$$\Delta T_{lm} = (210.59 - 92.0) \frac{921}{\pi\ 26.6} \left(1 - e^{-\frac{\pi\ 26.6}{921}}\right) = 113.1$$

Average film temperature

$$T_f = \frac{3 \times 210.59 + 92.0 - (210.59 - 92)\ e^{-\frac{\pi\ 26.6}{921}}}{4} = 153.89$$

$$Z_f = 1.18 \times 10^6$$

$$M_f = 0.0314$$

The average Grashof number,

$$Gr_f = 1.18 \times 10^6 \times 0.0314 \times 113.1 = 4.18 \times 10^6$$

The average Nusselt number from equation 2,

$$Nu = (0.0129 \times 921 + 11.40)\left(\frac{4.19}{1.5}\right)^{0.722 - 0.0911 \ln 921}$$

$$Nu = 25.805$$

Check if this value is within 0.001 of the test Nusselt,

$$26.6 - 25.805 = 0.795 \text{ (greater than } 0.001)$$

The value just obtained by the use of equation 2 is used to calculate a new Grashof number,

$$Nu_t = 25.805$$

$$\Delta T_{lm} = 113.2$$

$$T_f = 153.87$$

$$Gr_f = 4.183 \times 10^6$$

$$Nu = 25.805$$

This value is the same as the value for the test Nusselt number, and is therefore acceptable.

Error in the value for the Nusselt number as given by equation 2,

$$\text{Error} = \frac{25.805 - 26.025}{26.025} \times 100 = - 0.864$$

APPENDIX C

NOMENCLATURE

Latin

A	inside surface area of tube, $ft.^2$
c_p	specific heat at constant pressure $\frac{BTU}{lb_m\ ^oF}$
D	inside diameter, ft.
g	acceleration due to gravity, $\frac{ft}{hr^2}$
h	convection heat transfer coefficient, $\frac{BTU}{hr.ft^2\ ^oF}$
h_{fg}	latent heat of vaporization, $\frac{BTU}{lb_m}$
k	thermal conductivity, $\frac{BTU}{hr.ft\ ^oF}$
L	length, ft.
m	mass of steam condensate, lb.
$\dot{m}$	mass rate of flow, $\frac{lb}{hr}$
P	pressure, in. of Hg.
q	heat transfer rate, $\frac{BTU}{hr}$
T	temperature, ^oF
V	volume, $ft.^3$
$\bar{V}$	velocity, $\frac{ft}{hr}$
v	specific volume, $\frac{ft^3}{lb}$
W	width, ft.
x	axial distance from tube entrance, ft.

Greek

β coefficient of volumetric expansion, $\frac{1}{\circ F}$

Δ indicates an increment

γ specific humidity, $\frac{\text{lb water}}{\text{lb dry air}}$

μ dynamic viscosity, $\frac{\text{lb}}{\text{ft.hr}}$

ν kinematic viscosity, $\frac{\text{ft}^2}{\text{hr}}$

π 3.14159

ρ density, $\frac{\text{lb}}{\text{ft}^3}$

Σ indicates a summation of terms

τ time, sec.

Subscripts:

a refers to condition of air

d.b. dry-bulb

g refers to conditions of air at the gas meter

i number of condensate collection chamber, $i = 2,3,4, \ldots, 22$

lm based on logarithmic mean conditions

o based on inlet conditions

oa refers to section of tube where no condensate was collected

s refers to saturation conditions of steam

w refers to conditions at inside surface of tube

x based on local conditions

Moduli:

Gr Grashof, based on the inside tube diameter, and properties taken at the film temperature

Gz Graetz, properties based on the film temperature, $\frac{\dot{m} c_p}{k x}$

Nu Nusselt, based on the inside tube diameter, and properties taken at the film temperature, $\frac{h D}{k}$

Pr Prandtl, taken as a constant and equal to 0.70

Re Reynolds, based on properties of the air at the gas meter temperature, $\frac{V_o D}{\nu_g}$

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